UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Hudson River
PCBs SUPERFUND SITE

Engineering Performance Standards

Technical Basis and Implementation of the Resuspension Standard

April 2004

Volume 2 of 5

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Volume 2: Technical Basis of the Performance Standard for Dredging Resuspension

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List of Acronyms

ADCP	Acoustic Doppler current profiler
AMN	Water treatment facility (*formerly known as* SRMT)
ARARs	Applicable or Relevant and Appropriate Requirements
ATL	Atlantic Testing Labs
CAB	Cellulose Acetate Butyrate
CAMU	Corrective Action Management Unit
Cat 350	Caterpillar Model 350
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	cubic feet
cfs	cubic feet per second
CLP	Contract Laboratory Program
cm	centimeter
CPR	Canadian Pacific Railroad
CSO	Combined Sewer Overflow
CU	certification unit
CWA	Clean Water Act
cy	cubic yard(s)
DDT	Dichlorodiphenyltricholorethane
DEFT	Decision Error Feasibility Trials
DGPS	Differential Global Positioning System
DMC	Dredging Management Cells
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DQOs	Data Quality Objectives
DSI	Downstream of the dredge area inside the silt curtain
DSO	Downstream of the dredge area outside the silt curtain
EDI	Equal Discharge Interval
EMP	Environmental Monitoring Plan
EPS	Engineering Performance Standards
EQUIL	Software model used to determine chemical equilibrium between the particle-bound solid and the water column or aqueous phase
ESG	ESG Manufacturing, LLC
EWI	Equal Width Interval
FIELDS	Field Environmental Decision Support
FISHRAND	USEPA's peer-reviewed bioaccumulation model

FJI	Fort James Water Intake
fps	feet per second
FRRAT	Fox River Remediation Advisory Team
FS	Feasibility Study
ft	foot
ft^2	square feet
GE	General Electric Company
GEHR	General Electric Hudson River
GCL	Geosynthetic Clay Liner
g/cc	grams per cubic centimeter
g/day	grams per day
GIS	Geographic Information Systems
GM	General Motors
gpm	gallons per minute
GPS	Global Positioning System
HDPE	High Density Polyethylene
HUDTOX	USEPA's peer-reviewed fate and transport model
IDEM	Indiana Department of Environmental Management
JMP	a commercial software package for statistical analysis
kg/day	kilograms per day
lbs	pounds
LWA	length-weighted average
MCL	Maximum Contaminant Level
MCT	Maximum Cumulative Transport
MDEQ	Michigan Department of Environmental Quality
MDS	ESG Manufacturing model #. For example, MDS-177-10
MFE	Mark for Further Evaluation
MGD	million gallons per day
ug/L	micrograms per liter
mg/kg	milligrams per kilogram (equivalent to ppm)
mg/L	milligrams per liter
MPA	Mass per Unit Area
MVUE	minimum unbiased estimator of the mean
ng/L	nanograms per liter
NBH	New Bedford Harbor
NJDEP	New Jersey Department of Environmental Protection
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List

NTCRA	Non-Time-Critical Removal Action
NTU(s)	Nephelometric Turbidity Units
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OBS	Optical Backscatter Sensor
O&M	Operations and Maintenance
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCDFs	Polychlorinated Dibenzofurans
pcf	pounds per cubic foot
PL	Prediction Limit
ppm	part per million (equivalent to mg/kg)
PVC	Polyvinyl Chloride
Q-Q	Quantile-Quantile
QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
QRT	Quality Review Team
RCRA	Resource Conservation and Recovery Act
RDP	Radial Dig Pattern
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RM	River Mile
RMC	Reynolds Metals Company
ROD	Record of Decision
RS	Responsiveness Summary
Site	Hudson River PCBs Superfund Site
SLRP	St. Lawrence Reduction Plant
SMU	Sediment Management Unit
SOP	Standard Operating Procedure
SPI	Sediment Profile Imaging
SQV	Sediment Quality Value
SRMT	St. Regis Mohawk Tribe Water treatment facility (*former name for* AMN)
SSAP	Sediment Sampling and Analysis Program
SSO	Side-stream of the dredge area outside of the silt curtain
SVOCs	Semi-Volatile Organic Compounds
TAT	Turn-around Time
TDBF	Total Dibenzofurans
TG	turbidity generating unit
TI	Thompson Island
TIP	Thompson Island Pool

TM	turbidity monitoring
TOC	Total Organic Carbon
Tri+	PCBs containing three or more chlorines
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USI	Upstream of the dredge area outside the silt curtain
USO	Upstream of dredge area outside the silt curtain
USS	US Steel
VOC	Volatile Organic Compound
WDNR	Wisconsin Department of Natural Resources
WINOPS	Dredge-positioning software system used to guide the removal of contaminated sediment
WPDES	Wisconsin Pollutant Discharge Elimination System
WSU	Wright State University
WTP	Water Treatment Plant

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Hudson River PCBs Superfund Site
Volume 2: Technical Basis of the Performance Standard for Dredging Resuspension

1.0 Technical Background and Approach

This section provides a brief summary of the standard for reference throughout this volume of the text (subsection 1.1), identifies the basis for the standard as specified in the ROD, (subsection 1.2), defines terms used in this volume (subsection 1.3); identifies additional contaminants (subsection 1.4); discusses remedial design considerations (subsection 1.5); and provides an overview of case studies applicable to the approach (subsection 1.6) that are presented in detail in Volume 5 - Appendix.

1.1 Summary Statement of the Standard

A brief summary of the Resuspension Standard is included in this volume for convenience. A thorough statement of this standard is provided in Volume 1. In the formulation of the performance standard, several action levels were established so that remediation-related problems can be quickly identified and corrected before criteria are exceeded that would require temporarily halting the dredging operations. The resuspension criteria include Total PCB concentration, Total and Tri+ PCB[1] load, and suspended solids concentration thresholds. These criteria are defined in Table 1-1.

The Resuspension Standard includes criteria for both PCBs and suspended solids for both near-field and far-field conditions, which are defined as follows:

- Near-field conditions are those within a few hundred meters of the remedial operation. Only suspended solids criteria are applicable to the near-field stations.

- Far-field conditions are those at specific, permanent monitoring locations that are located at least one mile downstream of the remedial operation. Both PCBs and suspended solids criteria are applicable to the far-field stations.

Figures 1-1 and 1-2 depict the location of the near-field and far-field monitoring stations.

Compliance with the resuspension criteria is tested through monitoring. Tables 1-2, 1-3 and 1-4 contain the compliance monitoring requirements for this program. In addition to compliance monitoring, there are sampling requirements in the form of special studies to gather information that can be used to further refine elements of the standard. These studies include:

[1] Total PCBs refers to the sum of all measurable PCB congeners in a sample, while Tri+ PCBs refers to the sum of PCB congeners containing three or more chlorine atoms.

- Near-field PCB Release Mechanism (Dissolved vs. Particulate)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement
- Development of Far-Field Real-Time Suspended Solids Surrogate Measure
- Non-Target, Downstream Area Contamination

Implementation of the monitoring program is specified in Section 4, as are the required engineering contingencies in the event of exceedance of the resuspension criteria.

1.2 Record of Decision

As part of USEPA's responsibilities during the remedial design for the Hudson River PCBs site, the agency will develop an engineering performance standard that addresses the release and downstream transport of PCBs due to dredging operations. As specified in the Hudson River ROD (USEPA, 2002a):

> Performance standards will address (but may not be limited to) resuspension rates during dredging… These performance standards will be enforceable, and based on objective environmental and scientific criteria. The standards will promote accountability and ensure that the cleanup meets the human health and environmental protection objectives of the ROD. (ROD, page 88)

This standard is to be applied during the Phase 1 dredging effort and revised as necessary at the end of Phase 1 to reflect knowledge gained from the first year of dredging activities, as stated in the ROD:

> …The information and experience gained during the first phase of dredging will be used to evaluate and determine compliance with the performance standards. Further, the data gathered will enable EPA to determine if adjustments are needed to operations in the succeeding phase of dredging, or if performance standards need to be reevaluated. (ROD § 13.1, page 97)

The need for a performance standard concerning the release and downstream transport of PCBs was recognized in the ROD:

> …Although precautions to minimize resuspension will be taken, it is likely that there will be a localized temporary increase in suspended PCB concentrations in the water column and possibly in fish PCB body burdens. (ROD § 11.5, page 85)

This Resuspension Standard provides criteria to minimize the release of PCBs that are consistent with the rates of release anticipated in the ROD, while at the same time facilitating the removal of PCB-contaminated sediments from the river bottom. Like the residual and productivity performance standards, the ultimate goal of this standard is to:

> …ensure that dredging operations are performed in the most efficacious manner, consistent with the environmental and public health goals of the project. (ROD § 11.5, page 85)

The ROD also identifies several applicable or relevant and appropriate requirements (ARARs), and recognizes the need to conform to these federal and state requirements for water quality. These guidelines were considered, to the extent appropriate.

1.3 Definitions

Dredging is fundamentally a subaqueous earthmoving action. Just as ground-based earthmoving operations generate dust, dredging generates sediment particles that are released into the water column. Further, just as air currents spread dust from a construction site, ambient water currents transport resuspended sediments downstream. Resuspended sediments with particulate-associated PCBs increase water column PCB concentration, just as contaminated dust particles contribute to the total concentration of airborne contaminants.

In order to clearly describe the PCB release and downstream transport related to dredging, the following terms have been defined relative to the operation and distance downstream:

- ***Resuspension production rate***. Dredging-related disturbances suspend PCB-bearing sediments in the water column. The rate at which this occurs is the *resuspension production rate.*

- ***Resuspension release rate***. Since most of the sediments to be remediated in the Upper Hudson are fine sands, a significant fraction and often the majority of the small amount of material that escapes the dredge will settle in the immediate vicinity of the dredge. Materials that remain in the water column are then transported away by river currents. The rate of sediment transport in the immediate vicinity of the dredge is defined as the *resuspension release rate.*

- ***Dissolved-phase PCBs***. As suspended solids are transported away from the dredge, they will continue to settle, at the same time releasing a portion of their PCB burden into the water column, where the PCB is no longer bound to a solid particle. PCBs located within the water column but not bound to a solid particle are defined as *dissolved-phase PCBs* (smaller than 0.7 microns).

- ***Particulate PCBs***. As suspended solids are transported away from the dredge, they will continue to settle, while at the same time PCBs bound to the solid particles will be released into the water column. PCBs that are not released into the water column and continue to be bound with the suspended solids are defined as *particulate PCBs.*

Most of this settling takes place within a few hundred yards of the dredge. Given the extensive area of remediation in the Upper Hudson and its focus on depositional areas, it is expected that much of the material settling in the vicinity of the dredge will be collected during subsequent dredging passes.

- ***Resuspension export rate***. Beyond roughly one mile, further PCB removal from the water column by particle settling becomes small, and most of the PCBs in the water column are likely to travel long distances before being removed or captured by baseline geochemical processes such as volatilization or aerobic degradation. The rate at which PCBs are transported beyond one mile is defined as the *resuspension export rate*. It is this rate of PCB loss, with its potential for downstream impacts, that is the focus of the resuspension discussion in the ROD.

- ***PCB loss due to resuspension***. For the purposes of this performance standard, *PCB loss due to resuspension*, as stated in the ROD, is defined as the resuspension export rate just described. The standard addresses the net export of PCBs resulting from any activity related to the removal of PCB-contaminated sediments from the river bottom. This definition includes PCB export resulting from the dredging operation itself and from dredging-related boat movements, materials handling, and other activities. This definition requires both the disturbance and the downstream transport of PCBs from the source.

PCB loss due to resuspension requires both disturbance and downstream transport of PCBs from the source.

An important point is that the standard does not directly address the resuspension release rate or the resuspension production rate. These rates are considered only indirectly to the extent that they produce an export of PCBs beyond a distance of one mile downstream of dredging activity. Similarly, The standard does not regulate resuspension within engineered control barriers (*e.g.*, silt curtains), other than the extent to which resuspension within the barriers results in unacceptable export of PCBs downstream.

The Resuspension Standard does not regulate resuspension within engineered control barriers, except for unacceptable downstream export.

- ***Net export of PCBs to the Lower Hudson***. The *net export of PCBs to the Lower Hudson* is defined as the PCB resuspension export rate at the Waterford-Lock 1 Station, *i.e*., the load of PCBs at this location that is attributable to dredging-related activities. The Waterford-Lock 1 station was selected because it is downstream of the target areas identified in the feasibility study (FS) (USEPA, 2000b) but upstream of the Mohawk River, which was shown to be a minor but measurable source of PCBs to the Lower Hudson River (USEPA, 1997). The Federal Dam, which is the lower boundary of the Upper River, was not chosen because this location is downstream of the Mohawk River.

It is important to note that resuspension of sediments also results from other natural processes (*e.g.*, bioturbation and high-flow events) and anthropogenic processes (*e.g.*, the movement and actions of other vessels in the river). For instance, sediments are resuspended by propeller action during recreational boating activities or commercial shipping. Resuspension and any ensuing PCB export by these processes are accounted for by use of the baseline monitoring water column PCB concentrations in the development of the action levels.

In recognition of the nature of PCB release via resuspension, the Resuspension Standard addresses two areas with respect to dredging, the near-field area and the far-field area.

- ***Near-field area*** The *near-field area* is defined as the region in the immediate vicinity of the remedial operation, nominally extending from 100 feet (ft) upstream to 1 mile downstream of the remedial operation. This area represents the region of the water column most directly impacted by the remedial operation. The production of suspended solids by the dredge yields a resuspension release rate that controls local PCB levels in the water column. Resuspension and settling superimposed on the flowing river result in heterogeneous water column conditions in this area, making monitoring difficult. Each remedial operation has its own near-field area, although they can readily overlap, if deployed in the same vicinity.

> *Near-field area: the region in the immediate vicinity of the dredging, from 100 ft upstream to 1 mile downstream of the operation.*

- ***Far-field area*** The *far-field area* is the region well downstream of the remedial operations, beginning no less than 1 mile downstream of the dredging operation. Typically, by this distance downstream, the majority of particle settling related to dredging-related activities is expected to have occurred. Additionally, there has been sufficient travel time that water column conditions can be expected to be relatively homogeneous and, therefore, can be sampled in a representative manner with a manageable level of effort. At this point, PCBs in the water column resulting from dredging constitute the resuspension export rate and are considered to be available to contaminate downstream regions.

> *Far-field area: the region well downstream of the dredging, no less than 1 mile downstream of the operation.*

1.4 Contaminants of Concern in Addition to PCBs

Although much of the data collected for the Hudson River focuses on PCBs because these were selected as the contaminants of concern during the RI/FS, other contaminants (including dioxins and metals) may also be of concern in sections of the river. This performance standard does not address these contaminants. New York State is developing substantive water quality certification requirements for the environmental dredging pursuant to the federal Clean Water Act. The water column concentrations of compounds with certification requirements will be monitored during the remediation.

1.5 Remedial Design Consideration

Development of the performance standard for PCB loss due to resuspension will be done prior to the acquisition of the design support sampling, baseline monitoring sampling and the remedial design. As such, some broad and basic assumptions about the remedial design are required in order to construct the standard. The performance standard only specifies that the design must be able to achieve the performance standard; the standard does not dictate any other specifics of the remedial design. The equipment and procedures selected by the design team will be constrained in no other way by this standard.

As an example, the limits on the spread of resuspended sediments that may be afforded by the use of silt curtains or other barriers will not be considered in the development of the standard. The design team will determine whether these measures are required. Technologies and procedures that may be utilized to control resuspension are described and are based on an examination of the results from case studies and the analyses prepared for the Hudson River FS.

1.6 Case Studies

Preparation of the Resuspension Performance Standard included a review of previous monitoring programs associated with environmental dredging efforts. Review of historical case studies was conducted for both PCBs and suspended solids (turbidity or suspended solids). These studies provided a useful perspective on both the extent of dredging-related releases and the techniques used to monitor the dredging operation. While the Resuspension Standard was developed to be specific to the conditions of the Hudson River, these historical studies provided useful data used to support the selected criteria and requirements.

The PCB resuspension analysis that was completed for the *Responsiveness Summary (RS) of the Record of Decision* (USEPA, 2002a) provides detailed information on specific studies of PCB release. This work has been augmented here by the inclusion of a review of dredging-related turbidity issues. The applicable information from the case studies is summarized as appropriate under subsection 2.2, Supporting Analyses. A discussion of the case studies can be found in Appendix A to the Draft Engineering Performance Standard (provided under separate cover). Table 1-5 contains a brief summary of project information for the case studies reviewed for this standard.

2.0 Supporting Analyses

Supporting analyses were conducted during preparation of the Resuspension Standard to address and resolve issues pertaining to the impact of dredging and PCB transport from the dredge area to downstream locations. These analyses were completed to gather information and to gain an understanding on the following issues:

- What levels of turbidity or suspended solids have been observed at other environmental dredging sites? (Subsection 2.2.1)

- Does a correlation exist between suspended solids, turbidity and PCBs, so one can be a surrogate indicator of the other? (Subsection 2.1)

- What levels of PCB release have been observed at other environmental dredging sites? (Subsection 2.2)

- What are the baseline levels and variability of suspended solids and Total PCBs in the Hudson River water column? (Subsection 2.3)

- What is the upper bound baseline contaminant concentration per month or per season in the Hudson River? (Subsection 2.3)

- How will releases due to dredging be quantified relative to the ongoing releases from the sediments? (Subsection 2.4)

- How does the anticipated solids release from dredging compare to the baseline levels? (Subsection 2.4)

- By what mechanisms will dissolved PCBs be released and how does this compare with particulate PCB levels? (Subsection 2.5)

- Does the release of dissolved PCBs represent a significant impact that may occur from dredging? (Subsection 2.5)

- What would be considered a significant release (*i.e.*, resuspension export rate) from the dredging operation? (Subsection 2.6)

- How may potential releases affect human health and ecological risks? (Subsection 2.6)

- How much PCB may be released during dredging (*i.e.*, resuspension production and release rates)? (Subsection 2.7)

- At what rate will resuspended sediment settle out of the water column? (Subsection 2.7)

- How far downstream will the settling of resuspended material occur? (Subsection 2.7)

- How much material will be deposited and what is impact on the deposition areas outside of the targeted (dredged) areas? (Subsection 2.7)

- Where should monitoring be conducted to measure PCB mass loss from dredging? (Subsections 2.1 and 2.6)

- How far from the dredge should water quality monitoring be conducted and what parameters should be measured? (Subsections 2.1 and 2.7)

To address these issues, supporting analyses were completed to define a basis on which the standard could be established. Several of these issues were addressed as part of the analyses completed for the ROD. Other issues required further analysis. This section briefly summarizes these analyses and the conclusions drawn. Extensive descriptions of the analyses completed specifically for this standard can be found in the attachments to this document (Attachments A to G).

2.1 Turbidity and Suspended Solids at Other Sites

An evaluation was conducted to gather data concerning turbidity and suspended solids from completed dredging projects as well as current and design-phase dredging projects. The review of the available sites is extensively documented in Appendix A (Volume 4 of 4). Dredge sites previously researched during preparation of the Hudson River FS report and the Hudson River RS report were also included in this study. Among the issues addressed by this evaluation are the following:

- What levels of turbidity or suspended solids have been observed at other dredging sites?

- Does a correlation exist among suspended solids, turbidity, and PCBs, so that one can be a surrogate indicator of the other?

- How far from the dredge should water quality monitoring be conducted and what parameters should be measured?

These issues are specifically addressed in subsections 2.2.1 to 2.2.3, respectively. Table 1-5 provides a brief summary of the various sites where dredging-related turbidity or suspended solids data were available.

2.1.1 Reported Levels of Turbidity and Suspended Solids

In most dredging studies, turbidity was the main monitoring parameter.

In most dredging studies, turbidity was the main monitoring parameter. In several instances, data were also collected to correlate turbidity with suspended solids, with varying degrees of success. As to the absolute values of turbidity or suspended solids reported, most studies only noted the instances where conditions exceeded the site-specific criteria. This information is useful in that it can provide some examples of turbidity extremes related to dredging.

In most instances, the main area of turbidity or suspended solids monitoring was conducted in the near field, as defined previously. This is discussed further in subsection 2.2.3. In general, probe measurements or sample collection were most often performed within 1,000 ft of the dredging operation, although data were also obtained further away.

With regard to turbidity criteria, the review of case studies indicated that typical turbidity criteria were established at levels between 25 and 50 nephelometric turbidity units (NTU) above background levels. However, although many studies noted that turbidity monitoring was conducted during dredging operations, no turbidity threshold was provided in the reports, nor were data available for review. Instead, the reports concluded that turbidity never exceeded background levels. However, useful information on turbidity levels was obtained from some sites, as discussed below.

For New Bedford Harbor remediation in the lower harbor area, the turbidity standard was set at 50 NTU above background levels, 300 ft from the dredge. It was indicated that the 50 NTU standard was reached infrequently and further action was not needed since this level was not detected 600 ft from the dredge.

At the General Motors (GM) Central Foundry Division site (St. Lawrence River, Massena, New York), the turbidity threshold was set at 28 NTU. Turbidity measurements were periodically taken upstream and downstream of the dredge. When the value downstream exceeded the upstream value by 28 NTU, real-time turbidity measurements continued until the exceedance ended. Prolonged exceedances required modifications to the waterborne remediation activities until the problem was rectified.

During dredging at the GM Massena site, 18 of 923 turbidity samples exceeded the action level of 28 NTU above background (ranging from 31 to 127 NTU). These exceedances were observed at a depth of 1 ft below the water surface (except for one measurement at 9 ft). The duration of the exceedance was generally reported to be two to eight minutes, with two exceedances that lasted for 15 minutes and 45 minutes, respectively.

Both the reported values and the near-field turbidity criteria suggest maximum turbidity values around 25 to 50 NTU above baseline conditions. Few sites routinely reported all of their data, making further conclusions as to turbidity levels difficult. Suspended solids data were even more rare, and in most cases were assumed to correlate with turbidity.

2.1.2 Correlations Among Turbidity, Suspended Solids and PCBs

Information with regard to turbidity, suspended solids and Total PCB data and associated correlations was examined where available. Little data were available for most sites. However, for three dredging projects, an attempt was made to correlate collected data and draw a conclusion. In all three instances, however, the correlations were between turbidity and suspended solids. No correlations were reported between PCBs and either the turbidity or suspended solids parameter.

At the GM Massena site, bench scale tests were conducted prior to dredging to develop a relationship between suspended solids and turbidity. The following correlation was developed for overall conditions, including elevated suspended solids results (*i.e.*, >300 milligrams per liter [mg/L]):

$$\text{Turbidity (NTU)} = 7.3745+(0.611058 \times SS) + (0.00094375 \times SS^2);\ r^2=0.941$$

where: SS = the suspended solids concentration in mg/L.

Based on a regression analysis completed on the data set generated from the bench scale tests to determine whether a relationship existed between suspended solids and turbidity at lower concentrations (*i.e.*, when suspended solids values are less than 60 mg/L and turbidity values are less than 60 NTU), the foregoing equation was simplified to the following relationship by applying a linear fit curve to the plotted data set at lower concentrations, as indicated previously:

$$SS\ (\text{mg/L}) = [0.63 \times (\text{Turbidity})] + 6.8;\ r^2 = 0.43$$

where: Turbidity = the turbidity reading in NTU

Using this relationship, it was concluded that a turbidity value of 28 NTU corresponded to a suspended solids concentration of less than 25 mg/L. It should be noted that this relationship was the basis of the turbidity standard of 28 NTUs set for the dredging project. It can be concluded, in essence, that GM Massena's threshold was not only to maintain a turbidity of less than 28 NTU, but it was also to maintain a suspended solids concentration of 25 mg/L or less.

At the Cumberland Bay remediation site (Lake Champlain, New York), a technical specification set for the contractor was the development of a site-specific correlation between suspended solids and turbidity. This relationship was expected to yield action levels for the more easily measured parameter, turbidity, which in turn could be readily correlated to suspended solids action levels during the dredging operation. To accomplish this, the contractor performed bench scale tests prior to initiating dredging. The end result was that a reliable suspended solids-turbidity correlation could not be determined. This was attributed to unforeseen factors related to algae blooms and light refraction, which caused turbidity to vary in a way that precluded its direct correlation to suspended solids.

A similar series of bench scale tests was conducted prior to dredging at the Fox River Deposit N dredging site (Kimberly, Wisconsin). In addition to the tests correlating turbidity with suspended solids, studies were conducted to determine sediment resuspension and settling rates. The first steps were to submerge a 1-ft-thick aliquot of Deposit N sediment under 5 ft of river water and introduce forced air into the system to agitate it. Water samples were collected for turbidity and suspended solids analyses, and sediment settling rates were observed within the system.

The results of this study produced the following relationship between turbidity and suspended solids:

$$SS = -1.27 + 1.313 \times \text{Turbidity}; \quad r^2 = 0.98$$

Where:

SS = suspended solids in mg/L

Turbidity = turbidity in NTU

As a result of this relationship, suspended solids were estimated in the field during dredging based on real-time turbidity measurements.

Given the success observed for the two riverine sites, it may be possible to generate a site-specific relationship between turbidity and suspended solids for the Hudson River during Phase 1, or with a laboratory test prior to Phase 1.

2.1.3 Turbidity and Suspended Solids Monitoring

At the dredging projects examined, the locations of near-field monitoring generally included water quality monitoring stations upstream of the dredge, downstream of the dredge and to the side of the dredge (a side-stream station). At sites where containment such as sheet piling or turbidity barriers was deployed, monitoring stations were placed at the aforementioned locations outside of the containment area. Inside the containment area there were generally no monitors. If there were monitors, they did not have a specific threshold level to adhere to, but instead were used to evaluate the dredge operation itself. At sites where dredging was not contained, the monitor was located an average of 300 ft from the dredge. Monitoring locations for several of the larger sites examined are described below.

At the New Bedford Harbor Hot Spot dredging site, water quality monitoring stations were situated 300 ft from the dredge. This 300-ft radial area was referred to as the “mixing zone,” an area where environmental impacts were not directly monitored. There were no set threshold levels within the 300-ft area surrounding the dredge, as it was assumed that solids settling out within this radius from the dredge would not result in an adverse impact to the harbor. However, beyond 300 ft, it was assumed that solids would have the potential to impact downstream resources.

Another project at New Bedford Harbor, the dredging of the lower harbor, utilized the concept of the 300-ft mixing zone as well. For this project, a turbidity threshold of 50 NTU was set at the 300-ft distance from the dredge, as noted previously. In the event that the 50 NTU threshold was exceeded at this location, additional turbidity monitoring was required 300 ft from the location at which the exceedance was detected (*i.e.*, 600 ft from the dredge) to confirm the reading and assess the magnitude of the plume.

Many of the Commencement Bay dredging projects, located off the coast of Washington State, also utilized the concept of the mixing zone. No containment was used due to the tidally influenced waterways; however, monitoring was conducted at the limit of the mixing zone, which was typically established 300 ft from the dredge to ensure compliance with state and federal waterway regulations.

At the Grand Calumet River, Indiana, remediation site, monitoring is planned at locations both upstream and downstream, 300 ft from the dredge.

During dredging operations at the GM Massena site, water quality monitoring stations were positioned between 200 and 400 ft downstream of the sheet piling that enclosed the remedial operations.

Much of the available data on turbidity and suspended solids monitoring is focused in the near-field region, where turbidity measurement is the primary parameter. Monitoring locations are typically located 300 ft from the operation, with additional monitoring performed at greater distances on a less-frequent basis. These locations appear to have been selected based on professional judgment. Monitoring at these locations appears to have successfully measured the suspended solids transport from the vicinity of the remedial operations.

2.2 PCB Releases at Other Dredging Sites

PCB releases at other dredging sites were extensively explored as part of the RS for the ROD (White Paper – *Resuspension of PCBs During Dredging*, USEPA, 2002a). As part of this review, three sites were found to have sufficient PCB data to permit an examination of the rate of PCB release (see Table 2-1). Since the completion of the RS, no other sites have been found that have data to support a similar analysis. For two of these sites, GE Hudson Falls and New Bedford Harbor Hot Spots, monitoring around the location was sufficient to permit an estimate of the mass of PCB transported away from the site (*i.e.*, out of the near-field region).

This loading information was combined with information regarding the mass of PCBs removed to provide an estimate of the fraction of PCB lost. As noted in the white paper, the rates of loss observed for these sites (0.36% and 0.13%, respectively) are in close agreement with the 0.13% estimate presented in the FS for the Hudson River based on a dredging release model.

As discussed at length in the white paper, there were specific issues on sample collection techniques and sampling locations that compromised the data from the Fox River study in terms of developing a flux estimate. The PCB loss estimated for this site was 2.2%. In particular, the close proximity of the monitoring location to the dredging operation during portions of the study (less than 0.25 mile) was a significant factor impacting the data. These results suggest that much greater separation between source and sampling location is needed in order to correctly represent dredging-related losses. Nonetheless, although the magnitude of loss estimated is considered to be an overestimate, the rate of loss estimated by the US Geological Survey (USGS) for this site was considered in the modeling analysis in the RS, as well as later in this document.

2.3 Hudson River Water Column Concentration Analysis

Extensive study of PCB levels in the Hudson River was conducted during the Reassessment RI/FS; however, these analyses were focused on understanding the sources of existing loads and concentrations within the river. For the purposes of establishing a standard for PCB losses due to resuspension, it became necessary to develop a basis for distinguishing between dredging-related and preexisting baseline conditions. To this end, an analysis of the mean and variation of monthly conditions in the Upper Hudson was conducted using data obtained primarily through the ongoing post-construction remnant deposits monitoring program conducted by GE under a consent decree with USEPA. These data were also combined with flow data routinely recorded by USGS to provide estimates of PCB loads in the Upper Hudson.

The analyses, details of which are presented in Attachment A, were primarily intended to address the following two issues:

- What are the baseline levels and variability of suspended solids and Total PCBs in the Hudson River water column?

- What is the upper bound baseline contaminant concentration per month or per season in the Hudson River?

By establishing baseline concentrations and loads as well as the inherent variability of these parameters, it becomes possible to discern the additional contributions of PCBs originating with the remedial operations. That is, by establishing baseline conditions, deviations from these conditions can be identified and attributed to dredging-related releases as appropriate.

The following section briefly summarizes Attachment A of this report. The quantitative answers to the two issues cited above are found in the tables of the attachment and are not repeated here.
Post-1996 data collected by GE in the ongoing weekly sampling program were used in the baseline calculations, since they represent the most comprehensive water column

dataset and probably best reflect the current conditions in the Hudson River. Baseline conditions for suspended solids and Total PCB data were analyzed from this data set.

Three of GE's monitoring stations were analyzed for these purposes:

- Rogers Island (Fort Edward)
- Thompson Island Dam (TI Dam)
- Schuylerville

Results for both the PRW2 and the TID-West stations at TI Dam were examined separately. The data from Rogers Island is considered characteristic of concentrations and loads originating upstream of the remediation area. The TI Dam and Schuylerville stations are representative of conditions within the remediation area and are therefore important far-field monitoring locations. Although these data are extensive, however, the data may not be completely representative of the river conditions because of the sampling and analytical methods employed.

The examination was limited to the months of May through November, representing the expected dredging season. The data were examined on a monthly basis, in recognition of the significant month-to-month variation in conditions documented in the Reassessment RI/FS (refer to Appendix D1 of the FS). The analysis included the statistical characterization of each month for each station, establishing a basis for estimation of the mean and the variance of the population as a whole. Correlations with flow were examined as well and applied when significant and useful. Minor correlations with flow were ignored if the magnitude of the change in concentration or load was small.

Using these statistics, the following values were established for each month and station for both PCBs and suspended solids:

- The arithmetic average for a particular month

- The 95th%ile upper confidence limit (95% UCL) on the average value for the month

Data for adjacent months were combined when no significant difference was found between means and seasonal conditions were deemed similar (*e.g.,* May and June, October and November). The formula applied to estimate these factors was dependent on the underlying distribution of the data (*i.e.*, normal, lognormal, or non-parametric). Attachment A, Table 2, of this document contains a summary of these results.

June yielded the maximum concentrations in suspended solids at all stations; maximum PCB concentrations were observed in both May and June; and maximum upper confidence limits for suspended solids also occurred exclusively in June. Maximum upper confidence limits for PCBs proved to be less systematic.

The baseline concentrations and loads presented in Attachment A can be used as a basis to evaluate dredging resuspension during the remedial operation. At a minimum, daily Total and Tri+ PCB measurements will be obtained at the far-field stations. These results will be compared to the baseline values to determine whether the dredging-related releases are in excess of the load-based criteria. Similarly, suspended solids will also be used to identify dredging-related releases. In this instance, continuous or multiple daily measurements will be used to estimate the net suspended solids increase at the far-field stations. Net suspended solids increases above baseline will be considered indicative of dredging-related releases. See subsection 4.1 for implementation details.

Water column concentrations may on occasion be elevated above the upper confidence limits due to baseline processes, but it is unlikely that the concentrations will be elevated above these levels for sustained periods of time without an obvious cause (such as a flood event).

Each far-field station specified in the standard will be monitored during the baseline monitoring program. These baseline data will be used to revise the estimates of the averages and 95% UCLs at all stations and will form the basis for identifying dredging-related releases in Phase 1.

2.4 Resuspension Sensitivity Analysis

During the dredging operation, adequate monitoring will be essential to demonstrate that the resuspension criteria are adhered to and to verify that minimal downstream transport of PCBs occurs. An analysis was conducted to examine the impacts of plausible dredging releases relative to the estimated monthly baseline concentrations. Ultimately, this analysis was needed to address portions of the following issues:

- How will releases due to dredging be quantified relative to the ongoing releases from the sediments?
- How does the anticipated solids release from dredging compare to the baseline levels?

> *Baseline concentrations and variances were examined for two of the main far-field monitoring stations that established an average monthly concentration and an upper bound on the monthly mean concentration.*

Two analyses are summarized in this section that have a direct bearing on this analysis. In Attachment A, baseline concentrations and variances were examined for two of the main far-field monitoring stations, the TI Dam and Schuylerville. This analysis established an average monthly concentration and an upper bound on monthly mean concentrations. These data were then used in an analysis to estimate monthly loads for PCBs. A second important piece of information with respect to the estimated fractions of PCB mass that may be exported during dredging may be found in subsection 2.2. Values in case studies listed in Table 2-1 correspond to 0.13%, 0.36%, and 2.2% of the PCB mass removed. These values can be translated into an absolute mass export rate for the Upper Hudson remediation, as follows:

$$F_{dredge} = \frac{M_{UH}}{5yrs \times 7\frac{mo}{yr} \times \frac{30 days}{1mo} 14\frac{hr}{day}} \times L_{dredge} \times \frac{1{,}000g}{1kg}$$

where:	F_{dredge}	=	dredging resuspension export rate (or flux) in g/hr
	M_{UH}	=	mass of PCBs in the sediments of the Upper Hudson to be removed by dredging (69,800 kg or 150,000 lbs) in kg
	5 yrs	=	period of remediation (half year production in first and last dredging seasons with four full-production-rate years in between)[2]
	7 mo/yr	=	dredging season per year
	30 days/mo	=	days per month
	14 hr/day	=	expected mean dredging period per day
	L_{dredge}	=	dredging resuspension export rate as a fraction of removal (unitless)

By this formula, the three percentages given above (0.13%, 0.36%, and 2.2%) translate to PCB export rates of 6, 17, and 104 grams per hour (g/hour) of dredge operation, respectively. These values are comparable in magnitude to the nominal baseline daily flux of PCBs during the dredging season, generally ranging from 20 to 80 g/hr.[3] Thus the lower end of the possible export rates will be difficult to observe relative to the magnitude and variability of baseline fluxes as demonstrated in the variations discussed in Attachment A. In light of this observation, three nominal resuspension export rates were explored in this analysis: 0.5%, 1.0%, and 2.5%. These translate to 24, 47, and 119 g/hr respectively (or nominally 300, 600, and 1,600 g/day on a 14 hour/day basis).

Recognizing the anticipated range in river conditions over the dredging season, the analysis was conducted for Total PCBs in the Upper Hudson River over a wide range of river flow rates (2,000 to 10,000 cubic feet per second [cfs]). The suspended solids increase in the water column was estimated based on:

- Volume of sediment removed, the density of the sediment
- Dredging-induced resuspension export rate

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[2] This removal rate represents the target removal schedule in the Productivity Performance Standard.
[3] This range is based on a range of flows from 3,000 to 5,000 cfs and a water column concentration of 75 to 150 ng/L, typical of conditions in the TI Pool in June and July.

- Flow rate
- Length of the dredging season

Similarly, the Total PCB increase in the water column was computed as a function of:

- Mass of Total PCBs to be removed
- Dredging-induced resuspension export rate
- River flow rate
- Length of the dredging season

These results are presented in Attachment B of this performance standard. Because dredging-related export is calculated as a net addition of PCB or suspended solids (mass per unit time), the additional flux is independent of the river flow; however, the estimated increase in water column concentration will vary inversely with flow. For these estimates, dredging releases were not considered to be flow-dependent but rather to result from spillage, equipment handling, etc., all of which are independent of flow.

These estimated increases in concentration were then translated into a dredging-induced suspended solids and Total PCB concentrations in the river system. This was computed by adding the system's baseline variation of suspended solids and Total PCB concentrations (the estimated baseline concentrations) to the estimated increase in concentration (loading) as a result of solids loss from the dredging operation. Comparison of these potential in-river suspended solids and Total PCB concentrations were evaluated against the estimated suspended solids and Total PCB monthly baseline concentrations to determine the level of "significant" increase in the river system over baseline concentrations that signals an unacceptable dredging-related impact.

This analysis was completed for both monitoring stations at the TI Dam and for the Schuylerville monitoring station. Attachment B provides a detailed analysis for each monitoring station. The analysis identified periods of the dredging season wherein 600 g/day PCB export rate loading from the dredging operation would increase the Total PCB water column levels to a concentration just below 350 ng/L at the Schuylerville monitoring station. These elevated Total PCB water column concentrations were estimated for the months of May and June during low-flow conditions at the Schuylerville monitoring stations. Similar values were estimated for the TID-PRW2 station. Concentrations exceeding 350 ng/L were calculated for the TID-West station at low flow. In all three instances, however, the data may not be truly representative of the river conditions at the location, in light of concerns over collection techniques. Thus, any conclusions drawn from the data are tentative.

With the exception of estimated Total PCB concentrations during the months of May and June during low-flow conditions, it was concluded that 300 g/day and 600 g/day releases of Total PCBs due to dredging will correspond, overall, with a Total PCB concentration in the water column of less than 300 ng/L Total PCBs on average. This indicates that concentrations can be maintained below the 350 ng/L criterion of the Control Level. Generally, this analysis identified problematic times of year during the dredging season wherein extra care will need to be taken to maintain minimal releases from the dredge to avoid exceedance of the Total PCB concentration resuspension criteria. These results also suggest that if low-flow conditions occur during the months of May and June, less-contaminated areas might be chosen for remediation in favor of more highly contaminated areas.

A sensitivity analysis conducted on the annual PCB loading baseline evaluated the impact of dredging-induced PCB loading into the water column.

A sensitivity analysis was conducted on the annual PCB loading baseline to evaluate the impact associated with a dredging-induced PCB loading into the water column. This analysis was completed to evaluate whether the remediation of the Upper Hudson via dredging will have a measurable impact on the annual PCB loads. The baseline annual PCB loading was estimated for each of the monitoring stations for the period of 1992 through 2000 and compared to the dredging-induced PCB loading, assuming PCB export rates of 300 g/day, 600 g/day, and 2,300 g/day. The 2,300 g/day value corresponds to load conditions at the Resuspension Standard threshold for Total PCBs of 500 ng/L.

Assuming that dredging work would occur seven days per week and that the increase in concentrations would occur only during the 14-hour-per-day working period, the dredging-induced PCB loading for each of these scenarios was computed as a function of the following:

- Volume of sediment removed
- Total PCB concentration on the solids
- Induced Total PCB flux
- Section of the river being remediated

This analysis is presented in Attachment B of this document.

Analysis indicated:
A well-controlled dredging project exporting 300 g/day Total PCBs would release < 65 kg per year Total PCBs into the river.

A 600 g/day Total PCB export rate from dredging would result in approx. 130 kg/yr annual loading of Total PCBs to the river.

Comparison of the baseline annual PCB loading to the dredging-induced PCB loading for the three scenarios indicated that a well-controlled dredging project at full production (export of 300 g/day Total PCBs from dredging) would release less than 65 kg per year Total PCBs into the river as a result of the remediation, and that a 600 g/day Total PCB export rate from dredging would result in an annual loading of about 130 kg per year Total PCBs.

The Resuspension Standard threshold results in a 500 kg/year annual loading of Total PCBs to the river.

The Resuspension Standard threshold would result in an annual loading of 500 kg/year into the river. It can be seen that these rates of mass loss begin to become significant relative to the baseline annual loads. It was concluded that an annual dredging-induced 65 kg/year Total PCB loading is a relatively small fraction of the baseline load to the river in most years, and that the Total PCB load induced by the Resuspension Standard threshold is similar to PCB loadings that occurred in the early 1990s. This rate of export will be controlled through limits on the seasonal and daily rates of dredging-induced PCB export to prevent excessive PCB loss when the baseline PCB concentrations are low and the concentration criteria would allow higher export rates.

It is concluded from this analysis that the PCB concentration and load criteria established for the Resuspension Standard and action levels are protective of the river system and would generate Total PCB concentrations typically within the baseline variability of the river system.

Conclusions:
Annual dredging-induced 65 kg/yr Total PCB loading is relatively small fraction of baseline annual load to the river.

Resuspension Standard criteria and action levels are protective of the river system.

2.5 Dissolved-Phase Releases

Evidence has been reported from the Fox River study (USGS, 2000) to suggest that a large dissolved-phase release of PCBs is possible in the absence of any apparent increase in the water column loading of suspended solids. As a result, theoretical analyses were conducted to assess the potential mechanisms by which dissolved PCBs could be released into the water column. An attempt was then made to quantify the potential release of PCBs in the dissolved phase. The following issues were explored through theoretical analyses to estimate a quantity of PCBs that may be released into the river system in the dissolved phase:

- By what mechanisms will dissolved PCBs be released and how does this compare with particulate PCB levels?

- Does the release of dissolved PCBs represent a significant impact that may occur from dredging?

To some degree, resuspended solids lost from the dredge will release their PCB burden into the dissolved phase as the solids concentrations attempt to establish equilibrium. PCBs will continue to move from the particulate phase on the resuspended solid to the dissolved phase in the water column until a steady state is reached, a process that is otherwise known as establishing equilibrium.

PCBs move from the particulate phase on the resuspended solids to a dissolved state until a steady state, or equilibrium, is reached in the water column.

Once equilibrium is reached, the PCB concentration on the resuspended solid can be estimated, as well as the concentration of PCBs in the dissolved phase. Impacts of resuspension downstream of the dredging area can now be determined, since the PCB flux from the dredging area has been quantified. In addition, the quantity of dissolved phase PCBs released into the water column may have a significant impact on the water column quality, depending on the concentration and quantity of the dissolved-phase release.

There are two basic pathways by which dissolved-phase PCBs can be released into the water column:

- Through direct releases of pore water to the overlying water column as a result of the dredge's making a cut into the sediment
- Directly from a solids release/loss into the water column from dredging

Once solids are displaced into the water column, PCBs begin to partition from the particulate phase to the dissolved phase in an attempt to reach equilibrium within the system. In the event that the suspended solids added to the water column are of sufficient mass and contamination level, the dissolved-phase concentration will rise markedly. These analyses are described in detail in Attachment C to this document. A summary of the analyses assumptions, methodology, and conclusions are presented below.

The first theoretical model analyzed was the three-phase partitioning model, which was examined to evaluate conclusions drawn from PCB-loss calculations estimated for dredging conducted at the Fox River dredging sites. Specifically, the reported fraction of total mass loss as dissolved phase during dredging was approximately 1% of the total mass removed (USGS, 2000).

The three-phase partitioning model presented here assumes that the contaminant, PCBs, reaches equilibrium among particulate, truly dissolved, and dissolved organic carbon (DOC)-bound phases. This model was employed on a mass of contaminant-per volume of sediment basis. The three-phase partitioning model was evaluated using the Hudson River data. Detailed analysis and parameters used for this model can be found in Section 2 of Attachment C.

It was determined, using the three-phase equilibrium model, that the Hudson River sediment pore water contains very little of the *in situ* sediment PCB mass. More specifically, the three-phase partitioning model indicated that the dissolved phase represents 0.002% of the Tri+ fraction of PCBs relative to the sediment-bound PCB fraction of 99.998%. For the mono- and di-homologue fractions, the dissolved phase represents 0.004%, as compared to the sediment-bound PCB fraction of 99.996%.

These percentages of dissolved-phase PCBs per sediment-bound PCBs were then used to estimate the number of pore water volumes that would need to be displaced to achieve a 1% mass loss, as reported from the Fox River case study. The number of pore water volumes is computed as the proportion of water-to-sediment volume or the desired mass to be lost (1%) over the mass available in a single pore water volume (either 0.002% for Tri+ or 0.004% for mono- and di-chlorobiphenyls).

This computation estimated that 420 volumes of pore water would need to be released for the Tri+ fraction, or 210 cubic yards (cy) of water per cy of sediment, assuming the sediment are half water and half sediment. For the mono- and di-chlorobiphenyls, approximately 250 pore water volumes would need to be released, or 125 cy of water, assuming the sediment is half water and half sediment. It was concluded from this analysis that a direct loss of PCBs to the water column from the dissolved phase through the pore water would be highly unlikely, because such a large volume of water must be displaced to result in a measurable release of dissolved PCBs.

The amount of displaced pore water needed to achieve a measurable release of dissolved-phase PCBs is so high that direct loss of PCBs to the water column through pore water is highly unlikely.

Another analysis was the application of the two-phase partitioning model to estimate the distribution of the dissolved-phase PCBs to the total concentration of PCBs in the water column due to dredging. This analysis was conducted to evaluate whether it is sufficient to simply measure whole-water PCBs during dredging or whether the dissolved phase must also be measured if it is representative of a significant concentration. This model assumes equilibrium exists between the dissolved-phase fraction and the suspended phase fraction.

Data collected in the GE float surveys show that sediments continue to release PCBs to the water column throughout the year even when low-flow conditions exist and no observable resuspension is occurring in the system. Thus, for this analysis, a scenario was assumed in which a suspended solids concentration of 1 mg/L would be temporarily added to the system as a result of dredging. It was thought that evaluating the magnitude of PCBs in the water column for this scenario would allow for a preliminary evaluation as to whether the effects of dredging could be distinguished from the baseline river conditions.

In fact, the estimated fraction of dissolved phase PCBs estimated for the dredging-induced scenario in which suspended solids was released into the water column was similar to background concentrations. The fraction of dissolved phase to total water column PCB concentration for both background and after dredging is similar, on the order of 0.9. It was concluded that it is not possible to distinguish the effect of dredging by simply comparing the fraction of the dissolved phase increase in the water column.

Both of the foregoing analyses assume that the solids and dissolved phase PCBs reached equilibrium. Recent studies have indicated, however, that full chemical equilibrium may not be reached since the desorption rates of hydrophobic chemicals from sediment tends to be slow. It is thought that the residence time of a resuspended particle in the water column from dredging is relatively short (*i.e.*, on the order of hours). Assuming a few hours' residence time, it is not likely that the PCBs will reach equilibrium. In response to this concern, a literature review was conducted to obtain data on desorption equilibrium and kinetics of PCBs so this analysis could be carried out and evaluated.

The PCBs desorption rate constants reported in the literature are homologue-based, except for those of Carrol, et al. (1994), who used an untreated PCB that was comprised of 60% to 70% mono- and di-chlorinated biphenyls. The desorption rate constants were determined to vary between 4.2 x 10^{-4} to 0.2 hr^{-1}. The reported rate constants correspond to a half-life of approximately 3 to 1,700 hours and equilibrium times of 26 hours to 980 days. Given the length of time that it takes the PCBs to reach equilibrium, as described by these rate constants, it was concluded that it is highly unlikely that there will be large amounts of dissolved-phase PCBs released as a result of dredging. To validate this statement, the reported desorption rate constants were applied to the Hudson River sediment and dredging conditions. Applying these values into a kinetic rate equation, it was estimated that the dissolved-phase PCB released due to dredging may range from 7.6 x 10^{-5} to 3.2 ng/L, which is approximately 0.04 to 18% of the whole-water PCB concentration. These estimates indicate that the amount of dissolved-phase PCBs introduced into the system will be relatively small and comparable to background concentrations.

The theoretical analyses conclude that the release of a large amount of dissolved-phase PCBs is unlikely to occur as a result of dredging. It is possible to assess these results using field measurements of dissolved and suspended PCB concentrations in the water column during dredging, using the case study data. Measurements of dissolved- and particulate-phase PCBs were collected during the predesign field test conducted at the New Bedford Harbor during August 2000 (USACE, 2001).

The particulate PCB and suspended solids measurements taken during the dredging at New Bedford Harbor show patterns of concentrations similar to what would be expected during the remediation. At the point of dredging, the particulate PCB concentrations are elevated by a factor of about ten over the upstream conditions, but within 1,000 ft downstream of the dredge, the concentrations were only slightly greater than the highest measured upstream concentration. Turbidity levels drop off quickly with distance to upstream monitoring point conditions.

The dissolved-phase PCB concentrations at the dredge are again about ten times larger than the upstream concentrations but these concentrations drop off quickly into the range of the upstream samples. The upstream PCBs concentrations are about 60% dissolved. At the dredge this value drops to below 20%, indicating that PCBs released via dredging are primarily solids-bound. Downstream of the dredge the% of dissolved-phase PCBs is more variable but remain less than the 60% fraction at the upstream location. This variability in the downstream samples is mirrored in the particulate PCB and suspended solids measurements.

These results of this study are consistent with a mechanism of PCB release through the suspension of contaminated solids. This conclusion is more convincing in light of the high concentrations in New Bedford Harbor (860 ppm on average in the top 0 to 1 foot segment) relative to the Hudson River (approximately 50 ppm on average in the Thompson Island Pool [TI Pool]).

2.6 Far-Field Modeling

To study the long-term impacts of dredging, far-field modeling was used to simulate water column, sediment and fish Tri+ PCB concentrations in the Upper and Lower Hudson River as a result of the dredging operation. The far-field model was applied to determine the following:

- What would be considered a significant release (*i.e.*, resuspension export rate) from the dredging operation?

- How may potential releases affect long-term human health and ecological risks?

- What would be the short-term impact of an accidental release on the public water supply?

The modeling efforts were focused on examining the impact of running the dredging operation at the specified action levels in the Resuspension Standard. The water column, sediment, and fish Total PCB concentrations were forecasted using USEPA's peer-reviewed, coupled, quantitative models for PCB fate, transport, and bioaccumulation in the Upper Hudson River, HUDTOX and FISHRAND, which were developed for the Reassessment RI/FS.

HUDTOX was developed to simulate PCB transport and fate for the 40 miles of the Upper Hudson River from Fort Edward to Troy, New York. HUDTOX is a fate and transport model that is based on the principle of conservation of mass. The fate and transport model simulates PCBs in the water column and sediment bed, but not in fish.

For the prediction of the future fish PCB body burdens, the FISHRAND model was used. FISHRAND is a mechanistic time-varying model incorporating probability distributions. It predicts probability distributions of expected concentrations in fish based on mechanistic mass-balance principles, an understanding of PCB uptake and elimination, and information on the feeding preferences of the fish species of interest. Detailed descriptions of HUDTOX and FISHRAND models can be found in the *Revised Baseline Modeling Report* (USEPA, 2000c).

For the Lower Hudson River, the Farley *et al*. (1999) fate and transport model was used. The water and sediment concentrations from the Farley fate and transport model were used as input for FISHRAND to generate the PCB body burden estimates for fish species examined in the Lower Hudson.

As part of the modeling effort for the Resuspension Standard, the following scenarios were simulated using HUDTOX, FISHRAND, and Farley models:

- Dredging scenario with no resuspension release rate (HUDTOX run number d004).

- Dredging scenario with a net increase in Total PCB mass export of 300 g/day at the far-field monitoring stations (run number sr02). This essentially simulates the Evaluation Level of the Resuspension Standard.

- Dredging scenario with a net increase in Total PCB mass export of 600 g/day at the far-field monitoring stations (run number sr01). This corresponds to the Control Level of the Resuspension Standard.

- Dredging scenario with a maximum Total PCB concentration of 350 ng/L at the far-field monitoring stations (run number sr04). This corresponds to the Control Level of the Resuspension Standard.

- Dredging scenario with an accidental release during the 600 g/day dredging operation conditions.

Table 2-2 contains a list of completed model runs used in this report. Unlike the previous modeling efforts performed for the RS for the ROD (USEPA, 2002a), the model simulations completed for the Resuspension Standard track the sediment being resuspended as a result of dredging. The dredging scenarios with resuspension release were simulated with additional solids and Tri+ PCB loading to the model segments. In addition to simulating the "best estimate" of PCB resuspension release during dredging, the dredging schedule was shifted from 2004 to 2006, as seen in the start years listed in Table 2-3.

The resuspension scenarios in the foregoing bullets are specified as the PCB export rate at the far-field monitoring stations. Due to the nature of the HUDTOX model structure, PCB loads cannot be readily specified at far-field locations (*i.e.*, specifying the resuspension export rate). Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. In order to create a correctly loaded HUDTOX run, it is first necessary to estimate the local resuspension release rate from the dredging operation; that is, the rate of Total PCB and solids transport at the downstream end of the dredge plume. At this location most of the solids that are going to settle out will have settled out and the suspended solids will more closely resemble those simulated by HUDTOX.

Unfortunately, there is no direct way to establish the relationship between the resuspension release and export rates prior to running the models. To estimate the suspended solids flux input loading term for HUDTOX, a near-field model was developed (TSS-Chem) based in part on the work by Kuo and Hayes (1991). The Total PCB input loading term for HUDTOX (the resuspension release rate) was derived iteratively so as to obtain the desired PCB export rate at the far-field monitoring location. The resuspension release rate was obtained by checking the resuspension export rate (output from HUDTOX) until the model output gave the desired Total PCB export rate. Once the resuspension release rate that created the desired resuspension export rate was obtained, the corresponding suspended solids flux associated with the Total PCB release rate was estimated using TSS-Chem model. Detailed descriptions of the TSS-Chem and HUDTOX models and their use are provided in Attachment D.

The PCB export rate is not particularly sensitive to the amount of solids (suspended solids flux) loaded with the PCBs.

Appendix D contains a complete discussion on the effects of different formulations for suspended solids flux input to the model. From this study, it was concluded that the PCB export rate is not particularly sensitive to the amount of solids (suspended solids flux) loaded with the PCBs. A scenario with no solids added to the model segments increases the Total PCB export rate minimally (less than 15%) compared to the scenario with the suspended solids flux added derived from the one-mile plume scenario of the TSS-Chem model.

Figures 2-1 through 2-3 present comparisons of predicted HUDTOX Tri+ PCB concentrations in the water column at various locations throughout the Upper Hudson River for the monitored natural attenuation (MNA), no resuspension, and three action level scenarios over a 70-year forecast period.

The effect of running the dredging operations at the Evaluation Level (300 g/day) and the Control Level (600 g/day) on predicted water column Tri+ PCB concentrations is largely confined to the six-year active dredging period (2006 through 2011). Outside of the period of scheduled dredging (2012 and later), impacts on water column Tri+ PCB concentrations are minimal. However, in River Section 3 only, running the dredging operations at the Control Level or 350 ng/L (or 1,600 g/day) results in significantly higher water column concentrations during the dredging period and slightly elevated water column concentrations for approximately ten years after completion.

The cumulative Tri+ PCB load at Waterford as forecasted by HUDTOX was used to determine what would be considered a significant release (*i.e.*, resuspension export rate) from the dredging operation. Figure 2-4 shows the Tri+ PCB load forecasts for several load conditions. The lower bound will be the ideal conditions of dredging, where there are no sediments being spilled (no resuspension) and the upper bound will be the MNA scenario. The 300 g/day scenario was only simulated through 2020. From the figure, it was shown that the Tri+ PCB load for this scenario crosses the MNA by the completion of dredging (2011).

HUDTOX forecasts showed that Tri+ PCB cumulative loads for both 300 g/day and 600g/day scenarios would be lower than the MNA, suggesting acceptable loads to the Lower River.

The HUDTOX forecast for the Tri+ PCB load from the 600 g/day scenario remained higher than the MNA for a little longer, approximately four years after completion of dredging operations (2015). However, HUDTOX forecasts showed that Tri+ PCB cumulative loads for both 300 g/day and 600g/day scenarios would be lower than the MNA. This suggests that these two scenarios would yield acceptable loads to the Lower River. HUDTOX results for the 350 ng/L scenario showed that cumulative Tri+ PCB loads will go below the MNA cumulative loads for the 70-year forecast period. This suggests that by running the dredging operations at the Control Level of 350 ng/L for the entire program, significantly more Tri+ PCB mass will be transported to the Lower River relative to the MNA scenario, yielding an unacceptable amount of release.

Similar conclusions can be drawn for the Total PCB load estimates, although longer periods are estimated until the 300 g/day and 600 g/day dredging scenarios cross the MNA trajectory. These forecasts are considered less certain, however, since the models do not directly simulate Total PCBs, but rather Tri+ PCBs. The Total PCB estimates are based on estimates of Tri+ to Total PCBs in the resuspended sediments (refer to the *White Paper – Relationship Between Tri+ and Total PCBs* in the RS for more details [USEPA, 2002a]).

In addition to giving an indication of significant release, the results from HUDTOX runs may also provide an indication of the water column concentrations for the different dredging scenarios. Figures 2-5 through 2-7 show the whole water, dissolved phase, and particulate phase Total PCB concentration for the 300 g/day, 600 g/day, and 350 ng/L scenarios during the dredging period (2006 to 2011).

The HUDTOX model predicted that by running the dredging operations at the Evaluation Level (Total PCB flux of 300 g/day), the mean whole water column Total PCB concentrations at the TI Dam would be less than 160 ng/L. At Schuylerville and Waterford, the HUDTOX model predicted that the whole water column concentrations would average less than 120 and 80 ng/L, respectively (Figure 2-5). The water column Total PCB concentrations as a result of running the dredging operations at 600 g/day would be higher than those of the 300 g/day scenario, as expected. The mean whole water Total PCB concentrations at the TI Dam during the dredging period (2006 to 2011) for the 600 g/day scenario are predicted to be less than 250 ng/L except for few days in June 2008 (Figure 2-6). The whole water Total PCB concentrations at the Schuylerville and Waterford monitoring stations are predicted to be lower than 200 and 150 ng/L, respectively.

For the 350 ng/L scenario, as expected, the HUDTOX forecast shows that on average, the whole water Total PCB concentrations will be approximately 350 ng/L (Figure 2-7). The predicted Total PCB concentrations in the water column during River Section 2 dredging are higher than 350 ng/L because the forecast flow used in the model during that dredging period (August 16 to November 30, 2009) is about 15% lower than the historical average flow based on the USGS data. Therefore, the higher concentrations are expected. However, the average concentration during the entire dredging period for River Section 2 (August 16 to November 30, 2009 and May 1 to August 15, 2010) is expected to be around 380 ng/L.

Figure 2-8 depicts the annual species-weighted fish body burdens for human fish consumption at RM 189, 184, and 154. The fish concentrations used are the species-weighted averages, based on Connelly *et al*. (1992), and are considered to represent a reasonable ingestion scenario among the three fish species consumed to any significant extent by human receptors (anglers) (USEPA, 2000a):

- Largemouth bass – 47%
- Brown bullhead – 44 %
- Yellow perch – 9%

FISHRAND fish body burdens forecasts for the MNA, no resuspension, 350 ng/L Total PCBs, and 600 g/day Total PCBs scenarios were plotted in the figure. The 300 g/day scenario was not simulated since the Tri+ PCB loads to the Lower River are lower than both the 600 g/day and 350 ng/L scenarios. FISHRAND modeling results for the Upper River show that the impact of the 600 g/day scenario on fish tissue concentrations is largely confined to the dredging period in River Sections 1 and 2 (Figure 2-8), similar to the water column results from the HUDTOX model. In River Section 3, the impact to the fish tissue concentrations lasts about three years beyond the dredging period to approximately 2014.

The forecast results from the different dredging scenarios indicated that the impacts to fish tissue concentration would largely be short-term (*i.e.*, confined to the years during the dredging period) for River Section 1, even for the 350 ng/L scenario. The impact of the 350 ng/L scenario is slightly longer lasting in River Section 2 compared to that for River Section 1 (Figure 2-8).

Long-term human health and ecological risks are discussed in the following subsection.

2.6.1 Human Health and Ecological Receptor Risks

This subsection compares long-term risks (*i.e.*, after completion of dredging) from consumption of PCB-contaminated fish to anglers and ecological receptors (as represented by the river otter [*Lutra canadensis*]) under the following scenarios:

- No resuspension
- 350 ng/L Total PCBs
- 600 g/day Total PCBs
- Monitored natural attenuation scenarios

Risks were calculated with exposure durations beginning one year after the year in which dredging will be completed in the each section of the river and the average of the upper river (Table 2-3). Exposure durations (*e.g.*, 40 years for evaluating cancer risks to the reasonably maximally exposed [RME] adult angler, 7 years for evaluating non-cancer health hazards to the RME adult angler) and all other risk assumptions, locations, toxicity values, receptors, and fate, transport, and bioaccumulation models used here are the same as those used for baseline conditions throughout the Hudson River PCBs RI/FS in the *Revised Human Health Risk Assessment*, the *Revised Baseline Ecological Risk Assessment*, the FS, and the ROD Responsiveness Summary reports.

The fate and transport and bioaccumulation of PCBs in the upper river were predicted as Tri+ PCB concentrations using the HUDTOX and FISHRAND models. The Tri+ PCB group includes the PCB compounds that are most toxic to fish, wildlife, and humans and is considered to capture the majority of toxicity associated with PCB compounds. PCB contamination in fish tissue from the Hudson River has been shown to consist almost exclusively of Tri+ PCBs, with average values ranging from 98% to nearly 100% (USEPA, 2002).

The Revised HHRA and ERA (USEPA, 2000a and 2000e, respectively) have shown ingestion of fish to account for most of the risk to human and ecological receptors; therefore, the use of Tri+ PCBs for risk assessment modeling requires no revisions for comparison to available toxicological literature for PCB effects expressed as total PCBs or Aroclors.

The risk-based remediation goal (RG) for the protection of human health is 0.05 mg/kg PCBs in fish fillet.

Table 2-4 presents annual species-weighted fish fillet Tri+ PCB concentrations in the Upper Hudson River, as compared to the risk-based remediation goal (RG) for the protection of human health of 0.05 mg/kg PCBs in fish fillet. That RG is based on non-cancer hazard indices for the RME adult fish consumption rate of one half-pound meal per week and is protective of cancer risks as well. Other target concentrations presented are 0.2 mg/kg PCBs in fish fillet, protective at a fish consumption rate of one half-pound meal per month, and 0.4 mg/kg PCBs in fish fillet, protective of the central tendency (CT) or average angler who consumes one half-pound meal every two months.

The time to reach human health fish target concentrations of 0.2 mg/kg Tri+ PCB and 0.4 mg/kg Tri+ PCB in the Upper Hudson River was shorter for all resuspension scenarios as compared to monitored natural attenuation in the upper river as a whole and in River Sections 1 and 2 (Table 2-5). In River Section 3, all active remediation scenarios achieved the RG of 0.05 mg/kg Tri+ PCB prior to MNA. The greatest differences seen in the time to achieve fish target concentrations between the active remediation scenarios and MNA were seen in River Section 1, where the MNA scenarios took up to 17 years longer to achieve some target concentrations, while the smallest differences were seen between scenarios in River Section 3.

Using fish fillet concentrations based upon the three resuspension scenarios (*i.e.*, no resuspension, 350 ng/L, and 600 g/day), human health fish consumption cancer risks and non-cancer hazards show at least a 50% reduction in the upper river as a whole, Section 1 (River Mile 189), and Section 2 (River Mile 184) compared to monitored natural attenuation for both RME and average exposures (Tables 2-6 and 2-7). Risk reductions in Section 3 were seen for the no resuspension and 600 g/day scenarios as compared to monitored natural attenuation, but not for the 350 ng/L Total PCB scenario.

Based on site-specific angler surveys, the *Human Health Risk Assessment* (USEPA, 2000a) determined that Mid-Hudson River anglers have a different diet than anglers in the upper river:

- Brown bullhead – 53%
- Largemouth bass – 15%
- Yellow perch – 1.4%
- White perch – 7.6%
- Striped bass – 23%

Striped bass concentrations were not modeled for resuspension scenarios and therefore human health cancer risks and non-cancer hazards for Mid-Hudson River anglers could not be calculated. To provide an estimate of relative risks amongst the resuspension scenarios, angler intake was calculated using fish concentrations from the FISHRAND model. Striped bass intake was proportionally divided between the remaining fish species (i.e., 69% brown bullhead, 19% largemouth bass, 2.0% yellow perch, and 10% white perch) and white perch concentrations from the FISHRAND Model were used in the absence of Farley Model data.

Calculated fish exposure concentrations were used only for comparison between alternatives and do not represent predicted intake concentrations based on mid-river angler consumption patterns. As expected, fewer differences were seen between the resuspension scenarios in the lower river than in the upper river. Long-term cancer risks and non-cancer hazards differed by a maximum of 32%. The no resuspension and 600 g/day Total PCBs scenarios showed the greatest risk reductions as compared to monitored natural attenuation scenario. The 350 ng/L Total PCBs showed lower and sometimes no reductions in risk, owing to elevated concentrations of PCBs predicted in fish tissues for several years following dredging operations (Figure 2-9).

Risks to ecological receptors, as represented by the river otter, were evaluated by examining largemouth bass whole fish PCB concentrations. In the Upper Hudson River the lowest-observed-adverse-effect-level (LOAEL) target levels were reached within the modeling timeframe for the upper river as a whole and in Section 3 for all scenarios (Table 2-8). In the upper river as a whole, all resuspension scenarios reached the LOAEL target level of 0.3 PCBs mg/kg 17 years prior to the MNA scenario (Table 2-9). Ecological target levels were not reached within the modeling timeframe for Sections 1 and 2 of the river. In Section 3, all scenarios reached the LOAEL target level within five years of one another.

Largemouth bass PCB concentrations in the Lower Hudson River were lower under all resuspension scenarios than under the MNA scenario (Table 2-10). The LOAEL PCB target concentration in largemouth bass was reached 4 to 11 years sooner under the various resuspension scenarios than under MNA in various sections of the lower river (Table 2-11).

Resuspension may temporarily increase PCB concentrations locally, resulting in slight increases in fish PCB concentrations. However, human health non-cancer hazards and cancer risks and ecological

Conclusion:
Human health and environmental impacts from dredging are predicted to be

risks were calculated to be well below those under the MNA scenario. Minor differences were seen between the various resuspension scenarios, indicating the human health and environmental impacts from dredging are predicted to be minimal, particularly since levels of resuspension approaching the performance criteria are expected to occur on an intermittent, rather than continuing basis.

2.6.2 Accidental Release Short-Term Impacts

HUDTOX was used to model an accidental release scenario to demonstrate the short-term and long-term impacts to the public water intakes downstream of the incident. The following accidental release scenario was analyzed:

- A hopper barge containing 870 tons of silty sand (barge capacity is 1000 tons, with 87% sediment and 13% water) that has been removed by mechanical dredging from River Section 2 is damaged and releases the entire load in the area just above Lock 1.
- The contents fall in a mound and no effort is made to remove or contain the material.
- Over a period of one week, the entire load is swept downstream.
- The background concentrations are at the 600 g/day Total PCB flux at the River Section 3 monitoring location.
- For this scenario, an additional release of 113,000 kg/day suspended solids is anticipated, with a baseline condition of 20,000 kg/day for a one-week period (from July 1 through 7, 2011).

This scenario is quite conservative in that the average concentration from River Section 2 is higher than in the TI Pool. This is because areas with mass per unit area greater than 10 g/m^2 are targeted in this river section, whereas in the TI Pool, areas greater than 3 g/m^2 are targeted. The hopper barge was used because it has a larger capacity than the deck barge (200 tons) that was also proposed in the FS. The location of the accident is just above the public water intakes at Halfmoon and Waterford, minimizing the opportunity for reductions to the water column concentration resulting from settling and dilution.

Because a mechanical dredge is assumed to have removed the sediment, nearly the entire weight of the release would be attributed to sediment, with little dilution with water. The already elevated water column concentrations result in water column concentrations at the public water intakes greater than the MCL. This scenario is also conservative from the realistic standpoint that a spill of this magnitude would almost certainly be contained within hours of occurrence.

HUDTOX provided the whole water, particulate-bound, and dissolved-phase PCB concentrations in the water column. The model predicted that the accidental release scenario results in a short-term increase of the whole water Total PCBs above the MCL in the water column at Waterford (Figure 2-10); however, the highest dissolved phase Total PCB concentration was less than 350 ng/L (Figure 2-10). Because HUDTOX assumed instantaneous attainment of PCB equilibrium between the dissolved and suspended phases, the dissolved-phase PCB concentrations are overestimated, providing an additional conservative assumption.

While the Total PCB concentration entering the public water intake would be in excess of the federal and state MCL, it is likely that the concentration in the influent would be greatly reduced by minimal treatment because approximately 850 ng/L of the total 1,150 ng/L Total PCB peak concentration would be attributed to the suspended phase. Assuming that the bulk of the contaminated suspended solids would be removed by filtration, the delivered concentration without further treatment would be closer to the dissolved-phase PCB concentration of 300 ng/L. Thus, the water output from the plant would still meet the federal MCL of 500 ng/L.

As previously noted, the dissolved phase PCB concentrations estimated by HUDTOX are already biased high. The dissolved phase PCB concentrations would probably be further reduced by activated carbon treatment, which is currently implemented at the Waterford public water intake. This analysis suggests that the concentration reaching the public would be substantially less than the MCL even in the event of an accidental release in the vicinity of the intakes as described in the hypothetical accidental release scenario.

While this analysis suggests that the planned operations are unlikely to impact the public water supplies in the event of an accident, further consideration on the protection of public water supplies and the requisite monitoring will be given in the development of a community health and safety plan (CHSP).

2.7 Near-Field Modeling

Two models (CSTR-Chem and TSS-Chem) were developed to estimate the conditions within 1 mile downstream of the dredge head. These near-field models were used to estimate the suspended solids and Total PCB plumes resulting from resuspension of solids. The models were useful in identifying the most appropriate location for the placement of water column monitoring stations in the near-field and provided an estimate of solids transported into the far-field. In addition, the TSS-Chem model was used to estimate the effects of settled material on sediment concentrations within the near-field.

2.7.1 CSTR-Chem and TSS-Chem

CSTR-Chem and TSS-Chem models were developed and utilized for the near-field modeling effort to estimate the transport and concentration of suspended solids and Total PCBs from the dredge head to the far-field region (approximately one mile downstream of the dredge head).

2.7.1.1 CSTR-Chem

CSTR-Chem is used to model the area immediately around the dredge. The model is based on an ideal reactor configuration consisting of a continuous stirred tank reactor (hence CSTR). This construct represents a means to simplify the mathematical modeling of constituent concentrations in the immediate vicinity of the dredge head. CSTR-Chem assumes that a constant flow influent with a known constant concentration (*i.e.*, upstream river water) is instantaneously mixed as it enters a confined, well-mixed tank (*e.g.*, the region immediately around the dredge head). Physical and chemical reactions occur while the water is within the ideal tank and the tank effluent is at the same flow as the influent and at the uniform concentration within the tank.

The CSTR concept is most appropriate to the analysis of dredging operations because turbulence in the area of the dredge, coupled with ambient flows, may be assumed to produce mixed conditions similar to that in an ideal tank reactor. A complete discussion of the CSTR-Chem and TSS-Chem model development is presented in Attachment D.

The input for the CSTR-Chem is model is the subsequent resuspension rate. Since solids will settle within this area, the solids flux out will not be equal to the resuspension production rate of solids. The rate at which solids exit the immediate dredge area is termed the source strength. The source strength represents the solids available for downstream transport and is the input for the TSS-Chem model. However, since the TSS-Chem model simulates a point source and CSTR-Chem has a non-zero width, the two models cannot be directly linked. Nevertheless, CSTR-Chem can still be used to provide for input to TSS-Chem, particularly with regard to the dissolved PCB concentration and the silt fraction.

2.7.1.2 TSS-Chem

The TSS-Chem model has two components:

- A Gaussian plume transport model that describes the dispersion and settling of the particles downstream
- A geochemical component that uses two-phase partitioning of PCBs from solids into the dissolved phase taking into account a kinetic desorption rate

TSS-Chem utilizes the same solids transport equations for a mechanical dredge as DREDGE (Kuo and Hayes, 1991), outlined in Appendix E.6 of the FS and the White Paper – *Resuspension of PCBs During Dredging* (USEPA, 2002a). The TSS-Chem model was used to estimate PCB water column conditions downstream of the dredge across the width of the river up to a distance of one mile. TSS-Chem is useful for the near-field downstream transport of solids and PCBs but is inadequate in estimating the net contribution of solids and dissolved and suspended phase PCBs to the water column in the immediate vicinity of the dredging operations (*i.e.*, relating the resuspension production rate to the source strength). For this purpose, the CSTR-Chem model was developed.

2.7.1.3 Desorption Rate Input to the Models

One of the important input parameters in the CSTR-Chem and TSS-Chem models is the desorption rate constant. The conclusions drawn from CSTR-Chem and TSS-Chem models depend on an accurate desorption rate constant assumption. An extensive literature review on the PCB desorption rate constant was conducted for the Resuspension Standard and is presented in Attachment C. Due to lack of knowledge on the amount of "labile" (fast) and "non-labile" (slow) fractions in the dredged material, only fast desorption rate constants are considered in this study in order to provide a conservative (upper bound) estimate of the amount of PCBs that partition into the dissolved phase. The rate of desorption used for TSS-Chem and CSTR-Chem is 0.2 hr^{-1}. This desorption rate was applied to the difference between the PCB concentration of the suspended sediments and the equilibrium concentration by allowing more PCBs to remain in the water column with the existing soluble PCB concentration. Attachment D contains additional detail on the two-phase partitioning equations.

2.7.1.4 Applicability of the Models

Applicability of the CSTR-Chem model depends upon the presence of near-field conditions that can reasonably be represented as well mixed; it is important that the diameter of the cylindrical area that is approximated as a CSTR should reflect the extent to which well-mixed conditions exist. For the purposes of this analysis, a CSTR width of 10 meters (m) is used. Buckets that may be used in the Hudson River project are generally 2 to 3 m in diameter closed and somewhat larger when open. It was assumed that velocities induced by bucket movement could extend across most of a 10-m width used in this analysis.

The CSTR-Chem results suggest that under transient partitioning conditions, which are expected within the CSTR, the PCB releases from dredging operations will generally be less than 1% dissolved. The model results also suggest there is no significant loss of silt particles from the settling within the CSTR. The results of the CSTR-Chem model were used to develop the assumptions made concerning the source strength of the TSS-Chem model. The results indicated that:

- When the dissolved fractions estimated by the CSTR-Chem were input into the TSS-Chem, the results did not significantly vary from runs that had no initial dissolved phase.

- The silt fraction within the sediments is the only parameter that significantly affected the TSS-Chem PCB flux at one mile.

Incorporating these model observations, the TSS-Chem model was used to simulate the near-field dredging operations, from just beyond the dredge head to a one-mile distance downstream. Attachment D contains a more detailed discussion on the relationship between the TSS-Chem model assumptions and the CSTR-Chem.

2.7.2 Near-field Model Results

Near-field modeling was performed to address the following issues:

- How much PCBs may be released during dredging?
- How far from the dredge should water quality monitoring be conducted?
- At what rate will resuspended sediment settle out of the water column?
- How far downstream will the settling occur?
- How much material will be deposited and what is the impact on the deposition areas outside of the targeted (dredged) areas?

2.7.2.1 Solids and PCB Load HUDTOX Inputs

TSS-Chem was used to estimate solids and PCB loads for input to the HUDTOX model. Conditions at one mile were taken for input to the HUDTOX model, recognizing the difference in model scales. As outlined in Appendix E.6 of the FS (USEPA, 2000b) and *White Paper - Resuspension of PCBs During Dredging* (USEPA, 2002a), the average resuspension rate is based on a combination of field data from other sites and a resuspension model. The downstream transport rates (source strengths) only apply to silts and finer particles within the sediment (65% of cohesive and 20% of non-cohesive sediments for the Hudson River). The use of only silts does not significantly affect the PCB flux estimates because the silt resuspension rate, essentially equal to the silt source strength, is the driving source term for the PCB flux downstream

The production rates for the average source strength calculations were based on a total of five full production dredging seasons, using the estimated amount of sediment removal necessary and the time limitations involved. Each source strength estimate was run through TSS-Chem to calculate the resulting flux and concentration increases at one mile.

Table 2-12 contains the production rates, source strengths, and results are shown in. The average source strength was estimated at approximately 0.7 to 0.9 kg/s. For the various river sections these source strengths corresponded to PCB fluxes of approximately 80 to 210 g/day at one mile. The variation in the PCB fluxes for the different river sections is mainly caused by the different sediment concentrations. The highest flux is from dredging activities in River Section 2, which has a sediment concentration roughly 2.2 times greater than River Section 1.

2.7.2.2 Solids Transport Simulation

The TSS-Chem model was used to simulate the solids transport in the water column due to dredging operations up to one mile downstream. Simulations were performed for the 300 g/day, 600 g/day, 350 ng/L and 500 ng/L scenarios. The results suggest that the water column at one mile downstream of the dredge head has a significant amount of dissolved phase, but the suspended solids phase is still dominant (Figure 2-11). The fraction of dissolved phase Total PCB is greater for scenarios with lower amounts of solids introduced to the water column (*i.e.*, lower resuspension rates and source strengths) (Table 2-13).

For example, for the 300 g/day scenario, which has the lowest SS flux range from 0.3 to 1.3 kg/s at the dredge head, the TSS-Chem predicted that the fraction of dissolved phase Total PCBs one mile downstream of the dredge head ranges from 0.2 to 0.4 (Table 2-13). The 500 ng/L scenario has the highest amount of solids introduced to the water column (ranges from 3 to 9 kg/s at the dredge head). For this scenario, the TSS-Chem model results showed that the fraction of dissolved phase Total PCB in the water column ranges only from 0.05 to 0.1.

According to the TSS-Chem model results, the suspended solids concentration decreases and the width of plume increases as the solids are transported downstream. The suspended solids concentration at 300 m downstream is about one-quarter to one-third of the concentration at 50 m downstream, while the width of the plume at 300 m downstream is about twice the plume width at 50 m downstream. The greater width of the plume at 300 m suggests that this location may be easier to monitor using a stationary, continuous reading suspended solids sensor. It is also likely that by this distance downstream, water column concentrations of suspended solids will be more homogeneous. As a result, in an attempt to balance between the wider, more homogeneous plume conditions farther downstream and the easier identification of the center of the plume, 300 m downstream of the dredge head was chosen as the location of a primary near-field monitoring station.

The time that the particles remain suspended is primarily a function of the sediment type. Generally, silt particles will remain suspended longer than coarse particles. In the near-field models, the rate at which particles fall through the water column is determined by the particle settling velocity. Different settling velocities are defined for fine and coarse particles in the models. Attachment D contains a summary of settling velocities from various studies. For most of the studies, Stokes' Law was the theoretical basis for estimating the settling velocity of sand particles. This approach is appropriate for discrete particles that do not aggregate and was applied to the coarse material in the near-field models.

Stokes' Law only applies to discrete particles settling and does not account for flocculation during settling. Flocculation increases the rate at which silts settle from the water column, but the rate of flocculation depends on site-specific conditions and sediment properties. Therefore, silt settling velocities presented in QEA's report (1999) for Hudson River sediments were used in the near-field models, since these values were derived for Hudson River conditions and included the effects of flocculation.

The TSS-Chem results indicate that with a flow rate of 4,000 cfs, approximately 30 m downstream from the dredge head most of the coarse material has settled to the bottom of the river. At this distance, the coarse material is less than 0.1% of the net suspended solids from dredging. Since the coarse material settles much faster than the silts, it does not contribute significantly to PCB loads and concentrations at one mile. The results also suggest that there is a significant amount of settling within one mile downstream of the dredge head. The amount of Total PCBs being introduced to the water column from the dredge head is reduced by approximately 80% in River Section 1 and approximately 70% for River Sections 2 and 3 at one mile downstream of the dredge head (Table 2-13). For example, in River Section 1, when the amount of Total PCBs added to the water column due to dredging is 1,700 g/day, the load at one mile is approximately 400 g/day.

2.7.3 PCB Deposition Immediately Downstream at the Dredge Operations

If the suspended solids that settle onto the riverbed during transport downstream are contaminated, PCB mass and concentration will be added to the surrounding downstream areas. Using the modeled suspended solids concentrations in the water column downstream of the dredge, with the associated PCB concentration on the suspended solids, it is possible to estimate the increase in PCB mass in these areas. The increase in mass per unit area and the length-weighted average concentration of the top 6-in bioavailable layer were used to measure the effect of the settled material. Since these areas are outside of the target areas, the settled particles are not scheduled for removal.

If the suspended solids that settle onto the riverbed during transport downstream are contaminated, PCB mass and concentration will be added to the surrounding downstream areas.

The spatial distribution of the settled contamination will vary according to the shape of the target area and the rate of dredging. For this estimate, the target area is assumed to be 5 acres, 200 ft across, and approximately 1,100 ft long, because the areas of contamination are typically located in the shoals of the river and are narrow. From the FS, the time needed to dredge a 5-acre area with 1-m depth of contamination would take 15 days, operating 14 hours per day. It is assumed that the dredge will move in 50 ft increments across and down the target area. With these assumptions, the dredge will relocate approximately every two hours. To simulate the deposition of settled material, the amount of PCB mass per unit area, the mass of the settled material, and the thickness of the settled material that is deposited in two hours downstream at each modeled location is added on a grid as the dredge moves across and down the area.

Spatial distribution of the settled contamination will vary according to the shape of the target area and the rate of dredging.

The TSS-Chem results for each river section and action levels were used to estimate the additional mass per unit area and length-weighted average concentration approximately two acres downstream of the target area. The remediation could operate continuously at the Evaluation Level of 300 g/day and the Control Level of 600 g/day, but not the Control Level of 350 ng/L. The results are shown in Table 2-14.

The ROD defines 1 mg/kg as the acceptable residual concentration; the length-weighted area concentrations were calculated assuming that the PCB concentration in

The ROD defines 1 mg/kg as the acceptable residual concentration.

the sediment underlying the settled material is 1 mg/kg. In the two acres below the target area in River Section 2, for example, the concentrations range from 2 to 9 mg/kg.

These increases suggest that dredging should proceed from upstream to downstream if no silt barriers are in place, so that the dredge inside the target areas can capture settled material. Also, silt barriers may be needed to prevent the spread of contamination to areas downstream of the target areas have already been dredged or are not selected for remediation, as this settled material is likely to be unconsolidated and may be easily resuspended under higher flow conditions.

2.8 Relationship Among the Resuspension Production, Release, and Export Rates

During dredging operations, it is necessary to specify the near-field load to the water column that would yield the targeted export rates (*i.e*., resuspension criteria) at the far-field stations. In order to estimate these loads, computer models were utilized to provide a relationship between the far-field and the near-field dredging-induced PCB transport and loss. The TSS-Chem and HUDTOX models were used to represent and link the resuspension production (at the dredge-head), release and export rates. The resuspension release rate (and source strength) in the region from the dredge to a distance of one mile is represented by the TSS-Chem model. The resuspension export rate in the region beyond one mile is represented by HUDTOX.

The TSS-Chem and HUDTOX models were used to examine the:

- Amount of sediment being suspended in the water column at the dredge head.
- Suspended solids and Total PCB flux at one mile downstream of the dredge head.
- Total PCB flux at the far-field monitoring stations for the 300 g/day, 600 g/day, and 350 ng/L scenarios.

Table 2-12 shows the resuspension production, release, and export rates for the simulations. Because HUDTOX predicted different rates of export for different reaches of the river given the same PCB release rate, the TSS-Chem model was run under different conditions so as to yield a consistent output from HUDTOX *(e.g*., 600 g/day, 350 ng/L) for all river sections.

2.8.1 300 g/day Export Rate Scenario

To create a 300 g/day export rate of Total PCBs at the TI Dam, approx. 900-1,700 g/day Total PCBs would need to be suspended in bulk sediment, depending on distance between dredge head and monitoring station.

From the results, it was predicted that in order to create an export rate of 300 g/day of Total PCBs at the TI Dam, the amount of Total PCBs in bulk sediments that needs to be suspended is approximately 900 to 1,700 g/day, depending on the location of the dredge-head to the monitoring stations. The farther the dredge is from the far-field monitoring location, the greater the amount of solids and PCBs that would need to be suspended into the water column (Table 2-12).

Resuspension production rates that create an export rate of 300 g/day are on the order of 2% to 3% of the removal rate of Total PCBs via dredging. That means that in River Sections 2 and 3, the following amounts of Total PCBs in bulk sediment would need to be suspended from the water column are as follows:

- River Section 2: 1,000 g/day Total PCBs
- River Section 3: approximately 1300 g/day when the dredge head is farther away from the far-field monitoring location; around 1,000 g/day when the dredge head moves closer (downstream) to the monitoring station

Overall, the Total PCB resuspension export fraction relative to the PCB resuspension production rate for the 300 g/day scenario is estimated to range from 0.17 to 0.34.

2.8.2 600 g/day Export Rate Scenario

To obtain an export rate of 600 g/day Total PCBs, the amounts of Total PCB mass that would need to be suspended into the water column in the three river sections are as follows:

- River Section 1: from 3,000 to 4,000 g/day (on the order 5% to 6% of the Total PCB removal rate via dredging)
- River Section 2: approximately 2,000 g/day (approximately 2% of the Total PCB removal rate via dredging)
- River Section 3: approximately 2,000 to 3,000 g/day (on the order of 2% of the Total PCB removal rate by dredging)

Overall, the Total PCB export fraction relative to the PCB resuspension production rate for the 600 g/day scenario is estimated to range from 0.17 to 0.31, similar to that for the 300 g/day scenario.

2.8.3 350 ng/L Total PCB Concentration Scenario

The 350 ng/L Total PCB concentration at the far-field monitoring stations scenario was also simulated. The Total PCB fluxes at the TI Dam, Schuylerville and Waterford that would represent the 350 ng/L are 1,200, 2,000, and 2,300 g/day, respectively. The resuspension production rates, *i.e.*, the g/day volume of Total PCB mass that would need to be suspended to the water column to create an export rate of 350 ng/L Total PCB concentrations, are as follows:

- At the TI Dam: approximately 6,000 to 7,600 g/day (approximately 10% to 13% of the Total PCB removal rate via dredging)
- River Section 2: approximately 7,000 to 8,300 g/day (approximately 6% to 7% of the Total PCB removal rate via dredging)
- River Section 3: approximately 8,400 to 11,000 g/day (approximately 15% to 19% of Total PCB removal rate via dredging)

These resuspension production rates are approximately 19% to 24% of the Total PCB removal rate via dredging. The Total PCB export fraction for this scenario ranges from 0.16 to 0.28.

2.8.4 500 ng/L Total PCB Concentration Scenario

Modeling results suggest that from 16% to 29% of the PCB mass removed during dredging would have to be spilled to yield a 500 ng/L condition in the river.

The 500 ng/L Total PCB condition was only simulated by TSS-Chem model, without a subsequent HUDTOX model forecast. As a result, the Total PCB fluxes at the far-field monitoring stations were extrapolated based on the 500 ng/L input conditions and the results of the previous HUDTOX simulations. The TSS-Chem results for the 500 ng/L scenario suggest that the Total PCB export fraction of the resuspension production rate ranges from 0.16 to 0.29 (*i.e.*, 16% to 29% of the PCB mass removed would have to be spilled to yield a 500 ng/L condition in the river). To obtain 500 ng/L Total PCB concentration at the far-field monitoring station, g/day Total PCB mass that would need to be suspended to the water column would be as follows:

- River Section 1: approximately 10,000 to 13,000 g/day (approximately 17% to 23% of the Total PCBs removal rate via dredging).
- River Section 2: approximately 9,300 to 11,000 g/day (approximately 8% to 9% of the Total PCBs removal rate via dredging)
- River Section 3, approximately 13,000 to 16,600 g/day (approximately 23% to 29% of the Total PCBs removal rate via dredging)

Sediment spillage at levels that would be required in order to have long-term impact on downstream receptors and conditions is unlikely and well beyond what is expected for standard environmental dredging practices

These model calculations yield an important conclusion concerning criteria developed for the Resuspension Standard. While the model analysis of the concentrations and loads that comprise the standard show relatively little long-term impact on downstream receptors and conditions, the amount of sediment spillage required to attain these levels is quite large. Spillage at these levels is unlikely and certainly well beyond what is expected for standard environmental dredging practices. Based on these analyses, compliance with the Resuspension Standard appears to be attainable, including the lowest action criteria.

2.9 Review of Applicable or Relevant and Appropriate Requirements (ARARs)

The evaluation of potentially applicable federal and state water quality standards for the purpose of the performance standard development was based on work previously done for the ROD) for the Hudson River PCBs Site (USEPA, 2001). In the ROD, seven chemical-specific ARARs for PCBs were identified:

500 ng/L	Federal MCL [40 CFR § 141.61] and NYS MCL [10 NYCRR, Chapter I, Part 5, Section 5.1.52, Table 3]
90 ng/L	NYS standard for protection of human health and drinking water sources [6 NYCRR Parts 700 through 706]
30 ng/L	Federal Water Quality Criterion (FWQC) criteria continuous concentration (CCC) for saltwater [Aroclor-specific 40 CFR § 131.36]
14 ng/L	Federal Water Quality Criterion (FWQC) criteria continuous concentration (CCC) for freshwater [Aroclor-specific 40 CFR § 131.36]
1 ng/L	Federal Ambient Water Quality Criterion for Navigable Waters [40 CFR § 129.105(a)(4)]
0.12 ng/L	NYS standard for protection of wildlife [6 NYCRR Parts 700 through 706]
0.001 ng/L	NYS standard for protection of human consumers of fish [6 NYCRR Parts 700 through 706]

As long as the water column PCB concentrations are below the 500 ng/L federal and state MCL, protection of human health will be achieved.

Of these criteria, USEPA waived the three lowest concentration standards (0.001 ng/L to 1 ng/L) due to technical impracticality (USEPA, 2001), as it is technically impractical to reach these concentration levels in the Hudson River with the continuing input from the upstream sources. As long as the water column Total PCB concentrations are below the federal and state MCL (500 ng/L), protection of human health will be achieved. Only the 500 ng/L total PCB standard is not regularly exceeded by the main stem Upper Hudson River stations downstream of Rogers Island under existing (baseline) conditions; therefore, the other ARARs were not applied in the development of the Resuspension Standard. No other chemical-specific criteria were identified as ARARs or To-Be-Considered criteria (TBCs) in the ROD or the RRI/FS *Feasibility Study* (USEPA, 2000b).

Additional surface water quality criteria were considered for parameters that may be impacted by the remediation. These parameters are pH, dissolved oxygen (DO), and turbidity. NYS guidelines [6 NYCRR Parts 700 through 706] set the following standards:

pH	6.5 to 8.5 for Class A surface water
DO	Not less than a daily average of 6 mg/L for trout bearing waters; not less than 5 mg/L for non-trout bearing waters; and

Turbidity No criteria for surface water

Specific resuspension criteria have not been established for these water quality parameters. The water quality parameter data will be used for comparison to the continuously monitored data at both the near-field and far-field stations. These standards may be used as resuspension criteria in Phase 2, if appropriate.

2.10 Summary of Supporting Analyses

Numerous analyses were completed in support of this performance standard. Review of case studies have provided examples for the way the issue of resuspension of contaminated material has been handled at other sites leading to development of the elements of this standard, including resuspension criteria and monitoring and engineering contingencies. The calculations described suggest that the standard is achievable and, if complied with, will be protective of the environment and human health.

The context for these analyses will be evident in Section 3, Discussion of Rationale. A brief synopsis of the supporting analyses follows.

2.10.1 Turbidity and Suspended Solids at Other Sites

A surrogate measurement of suspended solids concentrations such as turbidity may become an important real-time indicator of PCB concentration levels, if it is proven in Phase 1 that the primary mechanism of contaminant release from the remediation is resuspension of sediment. Turbidity measurements are instantaneous, whereas analyses for suspended solids or PCBs are more time-consuming and limit the time available to warn downstream water supplies in the event of an exceedance of the standard.

> *Turbidity may become an important real-time indicator of PCB concentration levels, if Phase 1remediation indicate that the primary mechanism of contaminant release is resuspension of sediment.*

Case studies were reviewed to provide an indication of turbidity and suspended solids concentrations in the water column and the thresholds that were established at these sites to limit resuspension. Because suspended solids measurements are needed for comparison to resuspension criteria, a correlation must be developed between suspended solids and a surrogate before a surrogate measurement could be used for this purpose. Review of case studies and literature indicates that such correlations are site-specific, have been established at other sites, and could potentially be developed for the Hudson River. The case studies described the configuration of monitors relative to the remedial operations. This information was considered when specifying the near-field monitoring locations required by the standard.

2.10.2 PCB Releases at Other Sites

The case studies also provided information with which to calculate the amount of PCB released from other dredging sites. The rate of loss provides another indication of what a reasonable load-based resuspension criterion would be. These estimates of loss can also be used to determine the average increase in water column concentration during the remediation. Estimated rates of contaminant loss from other sites are 0.13%, 0.36%, and 2.2%.

2.10.3 Hudson River Water Column Concentration Analysis

Approximately five years of baseline water column PCB concentration data are available. Although there are concerns over the quality of these data due to the sampling methods and analytical methods used, estimates of the average expected water column PCB can be made. These values can be compared directly to the PCB concentration-based resuspension criteria to indicate whether, in some months, the PCB concentration may routinely approach the standard, even without the added impact of the suspension. The results indicate that the average PCB water column concentrations will be less than the concentration-based resuspension criteria, although in some months it is expected that the criteria would be exceeded on occasion.

2.10.4 Resuspension Sensitivity Analysis

The resuspension sensitivity analysis was built on the Hudson River water column concentration analyses by adding the estimated increase in concentration for a given increase in PCB load on to the estimated baseline PCB water column concentrations. This analysis suggests that the load-based resuspension criteria will not routinely elevate the water column concentration over the concentration-based criteria. The results indicate that the average PCB water column concentrations during dredging will be less than the concentration-based resuspension criteria, although in some months it is expected that the criteria would be exceeded on occasion. Variability in the water column concentrations may on occasion result in exceedance of the load-based criteria, although the true dredging-related releases are below the 300 g/day and 600 g/day Total PCB limits.

2.10.5 Dissolved-Phase Releases

A dissolved-phase PCB release undetected by a surrogate measure such as turbidity or suspended solids is not possible.

Concerns were raised during the public comment period for the Hudson River ROD that dissolved-phase PCB concentrations could be significant during remediation of PCB-contaminated sediment, and that a release of this kind could not be detected by a surrogate measure such as suspended solids or turbidity. The calculations described in subsection 2.5 indicate that a release of this kind would not be possible without an associated suspended solids release, because the bulk of the PCB contamination is bound to the sediment and there is not a sufficient amount of PCBs dissolved in the pore water to cause a substantial release.

2.10.6 Far-Field Modeling

The impacts of allowing the remediation to continue at the levels indicated by the resuspension criteria were determined through model simulation, using the fate, transport, and bioaccumulation models developed during the Reassessment RI/FS phase for this purpose. The results indicate that operation at the total PCB load-based resuspension criteria, which are the only criteria at which the remediation could operate for extended periods of time, will result in short-term impacts to the environment during the remediation, but will have little impact on the fish tissue concentrations post-dredging. Analysis of a hypothetical accidental release scenario in the vicinity of the Upper Hudson River public water intakes (subsection 2.6.2) indicated that although the concentrations entering the intake would be greater than the MCL, minimal water treatment would be sufficient to reduce the concentrations below the MCL.

2.10.7 Near-Field Modeling

Models of surface water concentrations in the vicinity of the dredge were developed to:

- Determine the amount of PCBs released from the dredging operation.
- Predict the downstream water column concentrations.
- Calculate the area in which the resuspended material would settle and the increase in PCB concentration in that area.
- Identify the appropriate locations for near-field monitoring.

The modeling indicated that the PCBs released by the dredge would be largely suspended phase. The amount of dissolved PCBs increased to a limited extent as the plume traveled downstream, but this process is slow because of the small coefficient of desorption. The relative amount of dissolved-phase to suspended-phase PCBs increases as the solids settle. Settling of contaminated material downstream of the dredge has the potential to raise surface concentrations substantially. This would be of concern if the area were not subsequently dredged, and may indicate the need for containment if this condition were verified. The results of these models suggest both the locations of the far-field and near-field monitoring points relative to the remedial operations and the suspended solids near-field resuspension criteria.

2.10.8 Relationship Among the Resuspension Production, Release, and Export Rates

The Total PCB load-based resuspension criteria were based on engineering judgment and the balance of several factors, including the:

- Best engineering estimate of resuspension production and export.
- Minimum detectable PCB load increase.
- Load defined by the water column concentration criteria.
- Impact of load on fish tissue recovery.
- Delivery of Total PCBs and Tri+ PCBs to the Lower Hudson.

Subsection 2.8 contains a detailed description of the selection process for the load-based criteria. A series of models was used to examine the relationship among the resuspension production, release, and export rates. The model calculations yield an important conclusion concerning the relationship between the resuspension production rate and the performance standard criteria. While the model analysis of the concentrations and loads that comprise the standards show relatively little long-term impact on downstream receptors and conditions, the amount of sediment spillage required to attain these levels is quite large. Spillage at these levels is certainly well beyond what is likely, given standard environmental dredging practices.

2.10.9 Review of Applicable or Relevant and Appropriate Requirements (ARARs)

Federal and state surface water quality guidelines were reviewed to determine if these regulations would provide a concentration level that was achievable during the remediation and protective of human health. The federal and state MCL of 500 ng/L total PCBs met these criteria.

3.0 Rationale for the Standard

3.1 Development of the Basic Goals and Resuspension Criteria

The performance standard for PCB losses due to resuspension is unique among the engineering performance standards in that the basic criteria are not defined in the ROD. Unlike the Production and Residuals Standards that have basic goals defined in the ROD (*i.e.*, approximately 2.65M cubic yards in six years and 1 mg/kg Tri+ PCB, respectively), the performance standard for PCB losses due to resuspension must justify both the ultimate numerical goals as well as the required implementation.

The remedial action objectives (RAOs) provide the ultimate basis for the development of the Resuspension Standard. As discussed in the 2002 ROD (USEPA, 2002a):

> [the] RAOs address the protection of human health and protection of the environment. (ROD § 9.1, page 50)

The RAO specifically addressed by this Resuspension Standard is the following:

> Minimize the long-term downstream transport of PCBs in the river. (ROD § 9.1, page 51)

In the ROD, the goal of the Resuspension Standard for PCB losses is defined in the following context:

> …Analysis of yearly sediment resuspension rates, as well as resuspension quantities during yearly high flow events, shows the expected resuspension due to dredging to be well within the variability that normally occurs on a yearly basis. The performance standards and attendant monitoring program, that are developed and peer reviewed during design, will ensure that dredging operations are performed in the most efficacious manner, consistent with the environmental and public health goals of the project. (ROD § 11.5, page 85)

And again:

> …Sampling and monitoring programs will be developed and implemented during the design, construction and post-construction phases to…determine releases during dredging…. These monitoring programs will include sampling of biota, water and sediment such that both short- and long-term impacts to the Upper and Lower Hudson River environs, as a result of the remedial actions undertaken, can be determined and evaluated. EPA will increase monitoring of water supply intakes during each project construction phase to identify and address possible impacts on water supplies drawn for drinking water. The locations, frequency and other aspects of monitoring of the water supplies in the Upper and Lower

> Hudson will be developed with public input and in consultation with New York State during remedial design. (ROD § 13.3, page 99)

Controlling the export of PCBs during the remediation will keep the water column concentrations close to current baseline levels and, by extension, keep fish tissue concentrations close to baseline levels during the remediation. In short, the goal of the standard is to ***minimize PCB losses during dredging to reduce risks to human and ecological health by controlling PCB exposure concentrations in drinking water and fish tissue.***

3.1.1 Development of Water Column Concentration Criteria for PCBs

As discussed in subsection 2.9, there are seven applicable chemical-specific ARARs for PCBs. Of these, the three lowest concentration standards (0.001 ng/L to 1 ng/L Total PCBs) were waived in the ROD, because it is technically impractical to reach theses levels in the Hudson River with continuing input from the upstream sources. Three of the remaining ARARs are concentrations that fall within the range of baseline conditions (14 ng/L to 90 ng/L Total PCBs) and cannot be considered for resuspension criteria during the remediation.

Only the 500 ng/L Total PCB MCL is a practical limit for use as a resuspension criterion, because this concentration generally falls outside of the baseline concentrations. The standard is written to permit a short-term increase in water column concentrations as long as the long-term goals of the remedy as defined in the ROD are met.

Only the 500 ng/L Total PCB MCL is a practical limit for use as a resuspension criterion, because this concentration generally falls outside of the baseline concentrations.

The river sediments are currently the primary source of the contamination in the Upper Hudson River and the removal of sediments is essential for the long-term benefit of the river. Additionally, removal of PCB-contaminated sediments will provide benefit to the remediated portions of the river during the remediation. As such, a limited amount of resuspension will be permitted because the benefits to the river outweigh the short-term impacts from dredging. This is consistent with the USEPA sediment principles recently promulgated by the Office of Solid Waste and Emergency Response (USEPA, 2002c).

Best management practices (BMPs) were considered as a basis for the standard. BMPs that could be implemented include structural and non-structural practices. Structural practices include:

- Containment.
- Shoreline restoration.
- Placement of backfill prior to removal of containment.

Non-structural practices include:

- Cessation of work at velocities above a set rate.
- Minimization of the use of boats with the potential to produce significant prop wash.

Structural practices are not required by this standard, because the locations where there is need for these practices should be identified during the design, when all available data can be fully analyzed. Similarly for non-structural practices, these requirements are specific to the equipment chosen and specific local conditions and are better set as requirements during the design. The cost, impact on productivity, and effectiveness of these practices should be carefully weighed prior to setting these requirements. It is expected that the design will include some best management practices to achieve compliance with the standard, but these will not be specifically required by the standard. Ulitimately, this standard is peformance-based and not prescriptive so as to encourage engineering innovation to protect the environment, optimize operations and complete the remediation as quickly as possible.

The most important ARAR for drinking water supplies is the federal maximum contamination limit, or MCL, for drinking water supplies, 500 ng/L Total PCBs[4]. This ARAR establishes the first of two objectives for the Resuspension Standard:

3.1.1.1 Objective 1 Development of Primary Criteria for Drinking Water

Drinking Water: Maintain PCB concentrations in raw water at drinking water intakes at levels less than the federal MCL of 500 ng/L.

The Resuspension Standard takes a conservative approach and is structured to achieve acceptable water column concentrations in raw water, regardless of WTP capability.

Objective 1 establishes a numerical limit on PCB concentrations in the Upper Hudson. Adherence to this level provides assurance that no public water supplies will be adversely impacted by the remediation, regardless of a given water treatment plant's (WTP's) ability to treat PCB-bearing water. Most of the WTPs potentially affected by the remediation have treatment systems that can reduce the concentration of PCBs in the finished water, although the current degree of reduction is unknown. For this reason, this standard will take the more conservative approach and not rely on this capability. Instead, this standard will be structured such that compliance with the standard achieves acceptable water column concentrations in the raw water.

Based on this objective, PCB export must be sufficiently controlled so as to prevent exceedance of the 500 ng/L Total PCBs level at the water supply intakes at Waterford and Halfmoon, New York, the first public water supply intakes downstream of the remedial areas. While dilution and degradation can be expected to reduce PCB concentrations in the water column during transit from River Sections 1 and 2 to the

[4] The New York State MCL is also 0.0005 mg/L Total PCBs (500 ng/L).

public water intakes, these processes cannot be relied upon while dredging in River Section 3. Thus, dredging in River Section 3 requires that PCB export due to dredging not result in water column concentrations in excess of the federal MCL. As a conservative approach for the protection of the water supplies, this same concentration level (500 ng/L Total PCB) is applied at all far-field monitoring locations and is the standard for water column concentrations (*i.e.*, the Resuspension Standard threshold).

An action level concentration limit of 350 ng/L, below the 500 ng/L federal MCL, will serve as a trigger for additional monitoring and engineering controls.

An action level criterion was also derived from Objective 1. Although the 500 ng/L level represents a level not to be exceeded, there is need for an action level below the MCL. Specifically, it is desirable to keep water column concentrations below the federal MCL while still meeting the productivity goals of the remedial operation. To this end, a second concentration limit of 350 ng/L Total PCBs was established. This value represents 70% of the MCL value and serves as a trigger for additional monitoring. This limit can also be derived from statistical considerations based on the variability of the water column concentrations and the analytical uncertainty in the PCB measurements, as described below.

No estimate exists of the likely variability of water column PCB concentrations in the Upper Hudson due to dredging. The variability of baseline conditions can be substituted as an initial estimate, or surrogate, although it is likely that dredging-related variability will be greater than the baseline variability. For the analysis that follows, the baseline variability of the Schuylerville station will be used. In order to scale this variability, the ratio of the standard deviation to the mean, (*i.e.*, the coefficient of variance $\left\lfloor \frac{\sigma}{\overline{X}} \right\rfloor$) will be used. For this location, based on the GE data set, the coefficient of variance (CV) is approximately 0.35. The 95th percentile is approximately 2 CVs, or 0.70 of the value. For the value of 500 ng/L Total PCB, this represents $\pm$ 350 ng/L Total PCB with a lower 95th percentile of 150 ng/L.

As can be seen in the table of baseline data in Table 3-1, this value is near or within the range of baseline variability and is thus not useful as an action level threshold.

As an alternative, it is also possible to determine a value that has no more than a 5% probability that the actual value is 500 ng/L Total PCB. That is, determine a threshold value based on the same CV such that 500 ng/L is the 95th percentile upper bound.

This is given as:

$$Y + 0.7 * Y = 500$$

where

Y = the threshold value

0.7 = 2*CV.

In this case, Y has a value of 294 ng/L, lower than the selected value of 350 ng/L.

If the Control Level were to require a response based on a single value, then this value, nominally 300 ng/L, might be a preferable choice over 350 ng//L. However, the Control Level is based on a one-week average, representing the mean of seven measurements. For an average, the upper and lower bounds are based on the standard error and not the standard deviation.

The ratio of the standard error (SE) to the mean becomes

$$\frac{SE}{\overline{X}} = \frac{\sigma / \sqrt{7}}{\overline{X}} = \frac{C_V}{\sqrt{7}} = \frac{0.35}{2.65} = 0.13$$

where 7 is the number of samples in the seven-day running average. In this instance, the equation for the threshold value using 2*SE becomes:

$$Y + 0.26 * Y = 500$$

This yields a threshold value of 397 ng/L. The selected value of 350 ng/L falls in the center of the two threshold estimates and is considered a good initial value for the program, given the unknown variance associated with dredging-related PCB concentrations.

Analytical precision must also be considered as it pertains to water column measurements. The precision of the historical analyses is quite good. At the Schuylerville station, the historical blind duplicate pairs yielded a median relative percent difference (RPD) of 8.1% and a mean RPD of 12.7% (see Figure 3-1). Ninety percent of all pairs had an RPD less than 22%. For an actual concentration of 350 ng/L, the mean RPD would suggest a possible analytical range of uncertainty of 328 ng/L to 372 ng/L (actual value + RPD/2). On this basis, the analytical variability should not limit the applicability of the 350 ng/L threshold value.

Engineering evaluations and improvements are required if the average concentration increase is 350 ng/L or higher for a week. These activities are required to identify and correct any potential problems that may cause a subsequent exceedance of the federal MCL, thus causing a possible disruption in the operations and requiring contingency actions on the part of the municipal water suppliers. This concentration threshold is defined as a Control Level criterion.

Compliance with these resuspension criteria at the far-field stations attains the objective and protects public water supplies during the remedial efforts. These criteria are designed to limit short-term impacts, since the river will deliver any resuspended PCBs to the downstream water supplies at Waterford and Halfmoon in a matter of days. However, the ROD clearly is also concerned with the impacts to fish and downstream consumers of fish. This concern requires a longer perspective, since fish integrate their exposure to PCBs over both time and area. Thus, fish tissue concentrations are likely to be more affected by a long, steady loss of PCBs than a single large release event. A second objective can be defined specific to this issue, as discussed in the following section.

3.1.1.2 Objective 2 Development of Primary Criteria for PCB Loads

Fish Tissue: Minimize long-term net export of PCBs from dredged areas to control temporary increases in fish tissue concentrations.

> *Short-term release of PCBs can be tolerated as long as the long-term average continues to satisfy the Resuspension Standard criteria.*

Objective 2 addresses the need to limit the impact of the remediation on the anticipated recovery of river after the remedial dredging is completed. This objective recognizes that the export of PCBs during dredging has the potential to slow the rate of recovery for fish body burdens and related exposures if it is sufficiently large. However, this objective also recognizes that it is primarily the long-term release of PCBs that has the potential to create an adverse impact. Short-term releases can be tolerated so long as the long-term average continues to satisfy the criteria.

In general, short-term releases are of the time scale of hours to days, while long-term releases are considered in terms of several weeks to months or longer. Thus, from the perspective of the ROD, the short-term releases are manageable so long as the eventual recovery of the river is not compromised. As noted in the ROD (USEPA 2002a):

> Although precautions to minimize resuspension will be taken, it is likely that there will be localized temporary increases in suspended PCB concentrations in the water column and possibly on fish PCB body burdens. (ROD § 11.5, page 85)

This objective can be approached from two perspectives:

- Ideal rate of PCB export
- Acceptable maximum rate of PCB export

The ideal rate is obviously no PCB release at all. However, this is also unattainable. The case study analysis presented in subsection 2.2 and the resuspension analysis presented in the RS (USEPA, 2002b) provide some useful target values, however. The two sites examined in subsection 2.2, the GE Hudson Falls remediation and the New Bedford Harbor Hot Spot remediation, achieved net PCB export rates of 0.36% and 0.13%, respectively, relative to the mass of PCBs removed. These percentages translate to Total PCB resuspension export rates of 240 and 86 g/day of operation, or 50 and 18 kg/yr on an annual basis for the remediation of the Hudson, respectively. These annual values represent only a small fraction of the annual baseline load of 260 to 400 kg/yr observed for the period 1996-2002 (see Figure 7 of Attachment B). Export at this level is unlikely to have any discernable impact on fish tissue concentrations, given the baseline variability.

In developing the load criteria for the standard, several different perspectives were examined to make the standard meaningful (*i.e.*, not too high) and achievable (*i.e.*, not too low). These include the following:

- Best engineering estimate of resuspension production and export
- Minimum detectable PCB load increase
- Loads defined by the water column concentration criteria of 350 and 500 ng/L Total PCBs
- Impact of load on fish tissue recovery
- Delivery of Total PCBs and Tri+ PCBs to the Lower Hudson (*i.e.*, Waterford load)

Each of these perspectives has the potential to provide some level of constraint on the selection of a PCB load criterion. Each is discussed below.

Best Engineering Estimate of Resuspension Production and Export

The best engineering estimate in the FS and RS estimated a Total PCB export rate of approximately 86 g/day (18 kg/yr), or 0.13% of the PCB mass to be removed from the river bottom.

The analysis presented in Appendix E.6 of the feasibility study (USEPA, 2000b) and in the responsiveness summary (USEPA, 2002b) provided an initial engineering estimate of the rate of PCB release from the dredge operation. The analysis estimated a resuspension production rate and a resuspension release rate, yielding an estimated Total PCB export rate of approximately 86 g/day (18 kg annually), or 0.13% of the PCB mass to be removed from the river bottom (69,800 kg).

The best engineering estimate analysis for the Resuspension Standard estimates a Total PCB export rate of approximately 90 g/day (19 kg/yr) or 0.14% of the PCB mass to be removed from the river bottom – only slightly higher.

In the preparation of the Resuspension Standard, the initial model analysis of suspended solids transport has been expanded and improved to more realistically represent conditions as well as to account for the kinetics of PCB dissolution. These results were discussed previously in subsection 2.7, and a detailed discussion is provided in Attachment D. These analyses confirm the results initially presented in the FS (USEPA, 2000b). The current analysis estimates a PCB export rate only slightly greater than the original estimate, at 90 g/day (19 kg annually[5]) or about 0.14% of the PCB mass to be removed. Based on these results, a best engineering estimate of approximately 20 kg per dredging season was selected as the target load value.

[5] The target PCB export rate of 19 kg/year represents a daily resuspension export rate of 90 g/day, assuming a 210-day dredging season (May through November) and seven days per week of operation. This is conservative in that operations less than seven days per week would effectively result in lower average daily export rates.

Although a target level of 90 g/day Total PCB would appear a desirable target (the analysis presented in the FS shows this loading rate to have a negligible[6] impact on the recovery of fish tissue concentrations throughout the river), this value does not account for activities other than the dredge operation. Boat movements, debris removal, barrier installation and removal, and other activities related to the dredging operation all have the potential to release PCBs, but are difficult to quantitate. Hence, a set of criteria is needed to define reasonable upper limits for dredging-related releases based on estimated impacts to the river. Much of the analysis described in subsection 2.2 was completed with the intention of providing input to the selection of these limits.

Minimum Detectable PCB Load Increase

An important limitation in selecting the PCB load criteria is the ability to measure the net increase in load due to dredging activities. Several considerations must be addressed in this regard. The selection of the far-field locations as the main PCB monitoring locations is a direct result of this concern. Baseline loads of PCBs originating from the sediments are similar in magnitude to those expected from dredging. Much of the sediment initially added to the water column will rapidly settle, releasing little or no PCBs. Hence the ability to detect a net PCB load increase in the poorly mixed region around the dredge operation (*i.e.*, at the near-field monitoring stations) is difficult and highly uncertain. For this reason, PCB monitoring will be conducted well away from the dredging operation (*i.e.*, far-field monitoring), where the net PCB load should be more stable and can be detected over baseline conditions.

Because it is unlikely that PCB export below 300 g/day (65 kg Total PCBs per yr) can be differentiated from baseline conditions, this value represents the minimum observable PCB export rate, or load.

As discussed in subsection 2.4 and Attachment B, this approach does have a limit on the ability to measure PCB export at a far-field station. Based on the historical variability observed in the available data, it is unlikely that PCB export below 300 g/day (65 kg Total PCBs annually[7]) can be differentiated from baseline conditions. This value then provides a minimum observable PCB export rate or load. Notably, the target load for PCB export due to dredging previously provided falls below the detectable load rate. Thus, if the best engineering estimate of an approximate 20 kg/dredging season export rate is achieved, there will be no measurable increase in PCB export. From a monitoring perspective, the goal for dredging is no observable increase in PCB load above baseline.

[6] A negligible impact in the Upper Hudson is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.5 mg/kg or less within 5 years after the cessation of dredging.

[7] This rate of PCB export corresponds to slightly less than 0.5% of the estimated mass of PCBs to be removed.

Loads Defined by the Water Column Concentration Criteria of 350 and 500 ng/L Total PCBs

The federal MCL provides a means to obtain an upper bound on the annual and daily load rate. If daily Total PCB concentrations remain at a monthly average concentration of 500 ng/L throughout the dredging season, the PCB export load can be calculated from the difference between 500 ng/L and the average baseline concentration for the month. This calculation yields an export rate of about 2,300 g/day (500 kg annually[8]). The 350 ng/L Total PCB resuspension criterion also provides a basis for a loading estimate.

1,600 g/day (340 kg annually) represents the likely maximum load derived from water column concentration criteria.

To maintain a weekly average concentration of 350 ng/L Total PCBs, the resuspension export rate must be approximately 1,600 g/day (340 kg annually[9]). For the purposes of this standard, the Control Level is expected to be the maximum operating condition, since concentrations above this level will require engineering improvements to reduce the releases. From this consideration, 1,600 g/day (340 kg annually) represents the likely maximum annual load that can be derived from the water column concentration criteria. This level cannot be maintained indefinitely, however, because the load-based limits are set at lower values [600 g/day].

Impact of Load on Fish Tissue Recovery

The ability to measure a net increase in PCB export relative to baseline conditions and the water concentration criteria provide potential bounding criteria for an acceptable export rate. However, it is still necessary to demonstrate that export rates at these levels do not substantively alter the recovery period of the river as measured by the decline in PCB concentrations in fish tissue. The model simulation for the best engineering estimate for resuspension presented in the responsiveness summary is the basis for comparison[10]. To investigate this, a series of model forecasts were conducted at resuspension release rates (near-field) and resuspension export rates (far-field) derived from the load considerations discussed in the foregoing subsections. The model runs dealing with long-range forecasts are summarized in subsection 2.6. The near-field model analysis is summarized in subsection 2.7. A complete discussion of the supporting model analyses is provided in Attachment D. Table 2-4 lists the completed model runs along with brief descriptive information.

Due to the inherent nature of the HUDTOX model structures, PCB loads cannot be readily specified at far-field locations. Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. For the

[8] This rate of PCB export corresponds to about 3.8% of the PCB mass to be removed.
[9] This rate of PCB export corresponds to about 2.4% of the PCB mass to be removed.
[10] Since the completion of the Feasibility Study, various factors and considerations have lead to a suggested start date for the remediation of 2006, instead of 2004 as originally planned. Since the best estimate simulation prepared for the Feasibility Study was barely discernable above the "no resuspension" simulation, the simulations prepared here were simply compared against a revised "no resuspension" result, reflecting the later start date. The 90 g/day best estimate condition was not rerun.

supporting model runs, the resuspension release rate was derived iteratively, by estimating the resuspension release rate (input to the model) and then checking the resuspension export rate (the model output) until the model output met the desired criteria. This process was necessary in order to make the model match the potential control criteria at the planned monitoring locations. These iterations also took into account the different river sections, with their corresponding target sediment properties (*i.e.*, silt fraction), PCB concentrations and hydrodynamics. The simulations also account for the changes in dredging location as the remediation progresses.

For example, to simulate the 350 ng/L Total PCB condition (*i.e.*, the Control Level threshold for the entire dredging program), it was necessary to provide the following loads in the three river sections:

- River Section 1: approximately 1,550 g/day Total PCBs and 56,000 kg/day of sediment
- River Section 2: approximately 2,300 g/day Total PCBs and 35,000 kg/day of sediment
- River Section 3: approximately 2,800 g/day Total PCB and 94,500 kg/day of sediments.[11]

These PCB and sediment loads reflect the differences in PCB concentration, river flow and monitoring locations among the three river sections. PCB and sediment loads had to be further varied to reflect the year-to-year movements of the dredges within each river section. As would be expected, less resuspension was necessary to achieve a specified PCB concentration or load at the far-field station the closer the dredge was to the station.

Model simulations for the 350 ng/L Total PCBs scenario were run to examine the impact of this criterion on the recovery of the river, using the recovery of fish tissue concentrations as the main measure (see Figures 2-8 and 2-9). This scenario showed some fish body burden increases during dredging but negligible[12] changes to fish tissue trajectories during the post-dredging period. After noting the negligible impact of the 350 ng/L scenario, there was no need to run a 300 g/day scenario since its impact would clearly be much less.

A 600 g/day Total PCBs scenario was run, based on its selection as a load criterion (see below). As expected, the 350 ng/L scenario has a greater impact than the 600 g/day scenario. However, both model runs indicate negligible[13] changes in fish tissue concentrations in regions downstream of the dredging. Within five years of the

[11] To put the suspended solids values in perspective, at a nominal flow rate of 4,000 cfs and 2 to 4 mg/L of suspended solids, the Hudson transports 20,000 to 40,000 kg of solids per day, respectively.
[12] A negligible impact in the Upper Hudson is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.5 mg/kg or less within 5 years after the cessation of dredging. In the Lower Hudson, it is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.05 mg/kg or less within 15 years after the cessation of dredging. Note that in the Lower Hudson, fish tissue concentration forecasts always agree within 0.5 mg/kg except for one year during the dredging period for the 350 ng/L scenario at River Mile 152.
[13] See footnote 12.

completion of dredging there is little discernable impact from the dredging releases based on the fish tissue forecasts. The model results suggest that compliance with the water concentration criteria previously developed (*i.e.,* 350 ng/L and 500 ng/L) will also minimize dredging impacts to the long-term recovery of the river.

Within five years of completion of dredging, there is little discernable impact from dredging releases, based on the fish tissue forecasts.

Delivery of Total PCBs and Tri+ PCBs to the Lower Hudson

In addition to recovery of the river as measured by fish tissue concentrations, impacts to the river due to dredging can also be gauged by the absolute mass of PCBs released. For this comparison, both Total PCBs and Tri+ PCBs are considered. The emphasis is placed on the estimated Tri+ PCB releases, however, since this is the fraction of PCBs that is bioaccumulative. This fraction is also far better understood from the perspective of sediment inventory and geochemical processes (the USEPA models simulate Tri+ PCBs).

As noted previously, the main consideration in developing a load standard is to minimize the release of PCBs. For this reason, the cumulative PCB load at Waterford, as forecast by the HUDTOX model, provides a useful gauge of any suggested loading standard. In this instance, the ideal condition is that given by the no resuspension scenario for the selected remedy. The upper bound would be the load delivered by the original monitored natural attenuation scenario (MNA). The forecast for acceptable load criteria would fall between the MNA and the no resuspension scenario.

The Tri+ PCB load forecasts for several load conditions are presented in Figure 2-4. The lowest curve, representing the least amount of PCBs transported downstream, represents the no resuspension scenario. MNA is also indicated on the figure. Because of the dredging-related PCB releases, all scenarios except no resuspension exceed the MNA forecast during the dredging period. Unlike the lower PCB release scenarios (see the upper diagram in Figure 2-4), the forecast curve corresponding to the 350 ng/L criteria never crosses over the MNA curve, indicating that setting the loading standard on the basis of this water concentration criterion would deliver significantly more Tri+ PCB mass to the Lower Hudson than MNA.

The 300 g/day scenario, equivalent to 100 g/day Tri+ PCBs (run to 2020), crosses the MNA curve just before the cessation of dredging. While this scenario was not run for the full forecast period, it is evident that the Tri+ PCB load level for the 300 g/day scenario would deliver much less Tri+ than the MNA. Also shown on the figure is a forecast curve for a Tri+ PCB load for the 600 g/day scenario, equivalent to 200 g/day Tri+ PCBs[14]. This curve also crosses the MNA forecast, just after the completion of dredging. On the basis of this analysis, both the 300 and a 600 g/day load standards would yield acceptable Tri+ PCB loads to the Lower Hudson.

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[14] This load is equivalent to 130 kg/year of Total PCB and 44 kg/yr of Tri + PCBs, or slightly less than 1% of the estimated mass of Total PCBs to be removed.

The impacts of the possible load criteria were also examined for Total PCBs, as illustrated in the lower diagram of Figure 2-4. These Total PCB curves are considered less certain, since the EPA models were developed to simulate Tri+ PCBs and not Total PCBs. Nonetheless they provide some guidance. The results from this analysis also show an unacceptably high Total PCB load to the Lower Hudson, based on the 350 ng/L criterion. Both the 300 and the 600 g/day forecasts show less total load delivered to the Lower Hudson than MNA, although the equivalence points occur later in time. The 600 g/day forecast crosses MNA about 20 years after the completion of dredging. The overall load difference between the 600 g/day scenario and MNA is relatively small, such that an increase in the daily load to 700 g/day would probably exceed the MNA curve. Given the uncertainties in the Total PCB estimates, the Tri+ PCB forecasts are considered the more reliable gauge among these scenarios.

Selection of a Load-Based Criterion

Taking into account the various considerations described above, it is clear that the target load of 90 g/day is not measurable, and the load equivalent to 350 ng/L delivers an unacceptably large mass of PCBs to the Lower Hudson. None of the load scenarios chosen as criteria yield an unacceptable impact on fish tissue concentrations, so this gauge is not useful here. The need to control PCB loads to the Lower Hudson provides the strictest limitation in the selection of a load criterion. This criterion is primarily based on Tri+ PCBs, the form of PCBs simulated by USEPA's models. Total PCB restrictions are more uncertain in this regard since they were not the focus of USEPA's models.

While no exact value results from this analysis, it is clear that the loading standard must fall between the ability to measure it (*i.e.*, 300 g Total PCBs/day detection threshold) and the 350 ng/L-based load of 1,600 g/day, which results in unacceptable loads to the Lower Hudson.

The loading standard must fall between the ability to measure – 300 g Total PCBs/day) and the 350 ng/L-based load of 1,600 g/day that results in unacceptable loads to the Lower Hudson.

A load of 300 g Total PCBs/day has been selected as a resuspension criterion, because it represents a best management practices goal. A load of 600 g/day, representing 130 kg annually, is the daily equivalent of the maximum allowable annual load and is also selected as a load criterion. It is twice the load detection threshold and therefore measurable. It is less than the 350 ng/L – 1,600 g/day condition and results in acceptable Tri+ and Total PCB load increases to the Lower Hudson.[15] In term of absolute loads, the 130 kg/year represents slightly more than a 40% increase in the mean annual load at Schuylerville (300 kg/yr for 1998-2002). Added to this value, the load increase would yield 430 kg/yr, which is just beyond the observed range at Schuylerville between 1998 and 2002 (180 to 410 kg/yr).

Relative to TI Dam loads, this 600 g/day load increase represents a 40% to 90% increase in the observed loads (TID West and TID-PRW, respectively) for 1996 to 2002. More importantly though, this load represents a nearly seven-fold increase relative to the best

[15] As was noted previously, the Total PCB load is not considered a robust constraint due to its uncertainty.

engineering estimate of 90 g/day, thus providing a reasonable allowance for other dredging-related releases (*e.g.*, boat traffic and debris removal). Yet as noted above, this load increment would have negligible[16] impacts on the long-term river recovery, generating only brief (one-to-two-year) increases in fish tissue concentrations relative to the MNA scenario.

600 g/day, the daily equivalent of a 650 kg load loss over the entire remediaion and 65 kg/yr in Phase 1, has been selected as the primary load criterion.

Based on these considerations, the value of 600 g/day has been selected as the primary load criterion: 600 g/day is equivalent to 650 kg load loss over the entire remediation and 65 kg/yr in Phase 1 assuming half the targeted production rate will be achieved.

Long-term maximum load loss limits of 650 kg Total PCBs and 220 kg Tri+ PCBs for the entire remediation have been derived from review of the model predictions. Adherence to these limits is important for the recovery of the river and protection of the Lower Hudson River. These limits have not been included as resuspension criteria directly, because these are end-of-remediation goals that do not fit within the performance standard structure. Indirectly these limits are implemented over shorter times frames, with daily limits for Total PCBs and Tri+ PCBs at 600 g/day and 200 g/day, respectively, and Phase 1 dredge season and annual limits of 65 kg and 22 kg, respectively, for the Phase 1 dredge season. As long as the load-based resuspension criteria are adhered to, the long-term load loss limit will not be exceeded.

The primary load criterion for Tri+ PCBs is 200 g/day, one-third that of Total PCBs.

Because Tri+ PCBs are the most important component of Total PCBs for the recovery of fish tissue concentrations, a load criterion is desired for this parameter as well. This criterion is simply derived from the Total PCB load criterion and the observation that the Total PCB to Tri+ PCBs ratio in the sediments is approximately 3:1. Since sediments are the main form of release of PCBs, it is expected that the net addition of Tri+ PCBs will be one-third that of Total PCBs, yielding a primary criterion for Tri+ PCBs of 200 g/day.

Evaluation and Control Level load criteria will be measured over 7-day periods by constructing a running average of Tri+ and Total PCB loads at all far-field stations for the entire dredging season.

The last consideration for selecting the load-based criteria is the time frame over which these apply. Taking into consideration the long-term nature of the load impacts and the likely high degree of short-term variability, the criteria should be based on longer-term conditions in order to avoid major disruptions to the operation due to short-term exceedances. For this reason, the Evaluation Level and Control Level load criteria will be measured over seven-day periods by constructing a running average of Tri+ and Total PCB loads at all far-field stations for the entire dredging season.

[16] A negligible effect in the Upper Hudson is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.5 mg/kg or less within 5 years after the cessation of dredging.

3.2 Rationale for a Tiered Approach

A tiered approach provides for additional sampling and appropriate engineering controls as PCB levels rise, thereby avoiding the need to cease dredging operations.

The actions levels (Evaluation Level, and Control Level) were developed to facilitate a steady level of remedial activities while still providing environmental protection. The tiered approach is intended to require additional sampling and engineering controls as PCB levels rise above those predicted by the best engineering analysis. This tiered approach provides action levels to trigger monitoring contingencies and implementation of additional engineering controls and thereby avoid a complete cessation in the operation. It is the intention of this standard to both minimize PCB losses and facilitate uninterrupted remedial operations.

In this approach, monitoring requirements will increase as the action levels are exceeded to provide data to clarify the nature of the PCB losses. These data can then be used to direct engineering control improvements while dredging operations continue unabated. The monitoring requirements will have no effect on dredging operations and productivity since there is no affect on the equipment and crews involved.

3.2.1 PCB Considerations

In developing the tiers of the standard, the need to control PCB export must be balanced with the need to comply with the federal standard. As extensively discussed in Attachments A and B, baseline water column PCB concentrations vary from month to month, necessarily complicating the structure of the standard. Based on these concerns, the PCB component of the Evaluation Level is a flux-based action level. The Control Level has both flux-based and concentration-based PCB criteria. Exceedance of absolute concentrations for the flux-based criteria at the Evaluation Level is not a concern in this instance. The purpose of the Evaluation Level is to control PCB export and potential long-term impacts to the recovery of the river.

The PCB concentration-based criterion of 350 ng/L is included in the Control Level to address the concern over exposure to PCBs through public water supplies as the MCL is approached. The duration for the exceedance is one week, based on a seven-day average in acknowledgement of the anticipated variability in water column conditions. As previously discussed, the federal MCL of 500 ng/L Total PCBs represents an absolute maximum concentration, the exceedance of which will cause the temporary halting of the remedial operations following confirmation of the concentration.

Exceedance of the Control Level 350 ng/L Total PCBs means the MCL is being approached and serves as an effective trigger for engineering controls.

The Control Level at 350 ng/L Total PCBs will be the effective maximum allowable level, since exceedance of this level means that the absolute maximum is being approached and that extra efforts are required to control PCB export. By requiring operations to maintain water column conditions below this value (350 ng/L Total PCBs), the Control Level provides a relatively large window of protection, decreasing the likelihood of a 500 ng/L Total PCB event.

When concentrations exceed 350 ng/L Total PCBs on average for one week or more, engineering evaluations and engineering improvements become mandatory until riverine conditions falling below the Control Level are achieved. Notably, months with high baseline concentrations will have relatively little "room to spare" and may require tight controls on the dredging operations to comply with this criterion. Exceedance of the Control Level may prompt temporary cessation of operations as deemed necessary by USEPA.

The monitoring and engineering requirements of the Control Level reflect the gravity of the exceedances. The increased sampling frequency is needed to have sufficient confidence in the results. These results may prompt costly engineering improvements if exceedance of the criteria is demonstrated. Extensive monitoring requirements and mandatory engineering controls are needed at this level to quickly identify the problems and render a solution, thereby avoiding a cessation of the dredging operation.

Exceedance of the 500 ng/L Total PCBs Resuspension Standard threshold requires cessation of operations if confirmed by sampling.

Exceedance of the Resuspension Standard threshold (500 ng/L Total PCBs) will require a cessation of operations if the exceedance is confirmed by samples collected the following day. If dredging-related PCB concentrations and loads increase gradually, there should have been at least two attempts (one for each of the two lower action levels) to understand and control any resuspension problem prior to the exceedance of the 500 ng/L threshold. Alternatively, a rapid rise in PCB concentration from baseline to more than 500 ng/L represents an unexpected and poorly understood event. In either case (*i.e.*, exceedance of the Resuspension Standard threshold), temporary halting of operations is required since conditions are clearly not as anticipated and may have significant consequences.

3.2.2 Suspended Solids Considerations

While PCB concentrations and loads are clearly the most important focus of this standard, determination of PCB conditions in the river is time-consuming, with a significant lag between the collection of samples and the availability of preliminary (draft) data. For this reason, it is desirable to measure and monitor parameters that correlate with PCBs and can be determined readily. Suspended solids, in particular, fit this requirement and have been selected for monitoring as well. Suspended solids measurements are reflective of short-term conditions, since the concentrations will vary rapidly in response to sediment disturbances. For this reason the suspended solids criteria will be derived from the water column concentration criteria described in subsection

3.1.1. Acceptable suspended solids concentrations were developed for both near-field and far-field conditions.

Resuspension release rates corresponding to PCB loads of 300 to 2,000 g/day are rapidly reduced in the near-field region, with resulting PCB export rates at the far-field stations 2 to 6 times less.

To further support the development of the suspended solids criteria, near-field conditions were simulated using a Gaussian plume model (TSS-Chem) to estimate the impact of various resuspension release rates. This analysis, summarized in subsection 2.7 and described in Attachment D, indicates that resuspension release rates corresponding to PCB loads of 300 to 2,000 g/day are rapidly reduced in the near-field region, with resulting PCB export rates at the far-field stations two to six times less than the release rates.

This analysis included an estimation of kinetically controlled PCB desorption, suggesting relatively minimal rates of dissolved-phase PCB release in the immediate vicinity of the dredge. In the region between 10 and 1,000 m downstream of the dredge, PCB loads steadily diminish while gradually decreasing the fraction borne by suspended matter relative to the dissolved phase. At the point of departure from the near-field region, PCB loads are primarily dissolved-phase, but overall the loads are substantively reduced compared to the immediate dredge area.

Analysis supports focusing the Resuspension Standard on solids-related release mechanisms, as it is apparent that the resuspension process alone controls PCB release within the dredging region.

It can be concluded that downstream export of PCBs (at one mile beyond the dredge operation) is unlikely to exceed the 300 g/day Total PCB Control Level on a regular basis. Furthermore, the analysis of suspended solids release and PCB desorption, presented in subsection 2.5 and Attachment C, indicates the resuspension process alone controls the PCB release within the dredging region. The creation of dissolved-phase releases by processes other than PCB desorption from suspended solids is highly unlikely, further supporting the focus of this performance standard on solids-related release mechanisms. This assumption will be tested by the separate phase PCB analyses to be completed as part of a special study.

Suspended solids criteria were developed for the Evaluation and Control Levels to provide a means to identify potentially significant PCB releases more rapidly. In most instances, suspended solids exceedances will necessitate additional PCB monitoring, which in turn should identify whether the PCB criteria are being exceeded. While these suspended solids criteria will require additional monitoring, it is the PCB concentrations, not the suspended solids concentrations, that will trigger the need for additional engineering controls. The additional monitoring will be limited to the far-field monitoring requirements for the nearest representative far-field station, with the sampling timed to capture the plume causing the exceedance. Near-field suspended solids sampling frequency will remain as a continuous surrogate measurement (turbidity) with an added suspended solids measurement (*i.e.*, 2 samples per day) to be obtained only at the noncompliant nodes..

3.2.3 Near-field Suspended Solids Criteria

The same suspended solids values are used for both the Evaluation and Control Level; only the duration of the exceedance varies between the levels.

Derivation of the suspended solids action levels is described in detail in Attachment D and briefly summarized here. The near-field suspended solids action levels were derived using the TSS-Chem model to simulate suspended solids conditions corresponding to the PCB concentration resuspension criteria.

For the Evaluation and Control Levels, suspended solids thresholds represent average suspended solids concentrations 300 m downstream of the dredge that would yield a Total PCB concentration exceeding 350 ng/L at the far-field station. The same suspended solids values are used for both action levels; only the duration of the exceedance varies between the levels. This was done to simplify the monitoring while still maintaining the ability to identify significant events.

A location of 300 m downstream was selected since the model suggests a plume width of 50 m and a relatively homogeneous water column at this distance. At this distance, it should be easy to reliably maintain a sensor in the plume and also minimize moment-to-moment variability in suspended solids measurements. If barriers are installed, this station will be placed 150 m downstream of the barrier. At these locations, a sustained concentration of 100 mg/L suspended solids in River Sections 1 or 3, and 60 mg/L suspended solids in River Section 2 will trigger an exceedance of either the Evaluation Level or the Control Level, depending on the duration of the exceedance.

Additional monitoring will be required at a location closer to the dredge to provide the operator with real-time information on the effectiveness of the dredge operations and the suspended solids controls. A distance of 100 m downstream of the dredge was selected as sufficiently downstream to provide some level of mixing and smoothing of the suspended solids signal while still being close enough to provide rapid feedback to the dredging operation. Feedback may be crucial in identifying operations or actions that cause excessive turbidity but can also be controlled to minimize water quality impacts.

Another station will be located 10 m to the side of the dredge nearest the channel. At these locations, a sustained concentration of 700 mg/L suspended solids will trigger an exceedance of the Evaluation Level. If barriers are in place, these stations will not have an associated resuspension criterion. In all cases, adjustment of the monitoring locations will be considered if alternate sites can be shown to be more effective to the monitoring goals.

Unlike the PCB criteria, the near-field suspended solids criteria should be prorated among all the active dredge operations in a given area, but for Phase 1, the concentration criteria for the suspended solids will apply to each operation individually.

3.2.4 Far-Field Suspended Solids Criteria

Far-field suspended solids criteria were developed for the Evaluation and Control Levels, reflecting the decreased sensitivity of suspended solids measurements at the far-field monitoring station. The suspended solids at the far-field stations are derived from the far-field PCB resuspension standard. The far-field suspended solids criterion was developed by simply calculating the amount of suspended solids that can result in a net increase of PCB concentration above the primary PCB criterion, assuming that the PCB concentration on the suspended solids is the same as on the dredged sediment The 500 ng/L far-field Total PCBs standard was used as a basis to calulate the suspended solids criteria for the far-field stations.

Assuming the baseline level of PCB concentration is approximately 100 ng/L Total PCBs, the net PCB concentration increase will be 400 ng/L Total PCBs. As stated in the responsiveness summary, the average Total PCB concentration on the dredged sediment across the three river sections is about 34 ppm. Based on these values, the increase in suspended solids concentration above baseline is calculated to be about 12 mg/L. This increase in suspended solids concentration must occur across the entire river and not just within the dredge plume for the associated PCB concentration increase to occur. This level (12 mg/L suspended solids increase) is close to baseline variability, however.

Considering the uncertainty in the calculation assumptions as well as the baseline variability in suspended solids concentration, a value twice 12 mg/L, *i.e.*, 24 mg/L, was also selected. As a result, the Control Level uses 24 mg/L suspended solids as the far-field suspended solids criterion. The Evaluation Level uses approximately half of this value (12 mg/L suspended solids), with a shorter duration. The periods of exceedance are the same as those for the near-field suspended solids action levels. The increased monitoring requirements will be limited to the nearest downstream far-field station, with the sample collection timed in order to capture the plume.

Due to the variable conditions within the river over time, some action levels may conflict with one another, particularly in May and June when baseline concentrations are relatively high. In these instances, the Control Level criteria for Total PCB concentration may be exceeded even though the Total PCB load does not exceed the Control Level criteria. The concentration-based action levels will govern the response, since these levels are intended to provide protection for the downstream public water supplies and therefore represent the more protective criteria in these instances.

Similarly, the suspended solids criteria may identify potentially important PCB concentration or load conditions that are not verified by subsequent PCB sampling and analysis. Exceedance of the suspended solids criteria prompts limited additional far-field sampling to determine the PCB concentration in the plume as it reaches the far-field station. These additional samples are incorporated in the equations used to determine whether the water quality levels are in compliance with the standard (subsection 4.1). In all cases, exceedances of the action level criteria by any parameter (*i.e.,* Total PCBs, Tri+ PCBs, or suspended matter) will spur additional monitoring requirements in order to have a sufficient number of samples from which decisions can be made from the data with confidence.

3.3 Monitoring Rationale

The rational for the standards describe above supports the framework and criteria which form the Resuspension Performance Standard. Monitoring to verfy comliance or excedance of the standard criteria is an integral part of the framework. This section presents the overall rationale for the monitoring program as it is currently configured. Significant adjustments to the monitoring program can only be made after the impacts of the adjustments are evaluated in one or more special studies. Adjustments to certain portions of the monitoring program may prompt evaluation of other aspects of the sampling and possible revision of the resuspension criteria. For example, an alternate monitoring program using automatic samplers to collect the PCB samples is presented in Section 4.

As noted in the ROD (USEPA, 2002a), the export of PCBs from the dredging area to regions downstream is the ultimate concern of this performance standard, since it affects both fish and public water supplies. Thus, the most important monitoring stations are those that monitor the rate of PCB export downstream. This increase in PCB export can be best and most easily measured at sufficient distance downstream of the dredging operation so that the river can homogenize the water column inputs from dredging. This distance should also be sufficient to avoid the inclusion of solids suspended during dredging that will settle in close proximity to the dredging operation and thus not represent a source to regions downstream.

Based on historical evidence as well as concerns highlighted by the Fox River study (USGS, 2000), these stations will be used for direct comparison with the Resuspension Standard criteria only when the stations are at least one mile downstream of the dredging operations. Baseline PCB conditions will be well characterized at these locations, allowing the load increase due to dredging-related operations to be measured. In the near field, the baseline is not characterized and may be highly variable.

Since the dredging program extends over nearly 30 miles, with potentially impacted downstream water supplies as far away as 100 miles from the TI Dam, the far-field monitoring program will consist of several major monitoring locations that can be readily and regularly occupied to obtain water column samples for PCB analysis. It is important to measure the PCB concentrations and the PCB mass loading from each of the river sections. In addition to showing how much mass is exported from each of the river sections, the size of the region subjected to the PCB export can be determined. Additionally, water treatment plants downstream can be notified in the event of a large release.

3.3.1 Far-Field Concerns

Because of the importance of the Hudson River as a public water supply and the need to assure public safety, daily samples will be collected at all far-field monitoring stations. Discrete samples will be collected from each station to represent the entire river cross section (*e.g.*, an equal-discharge representation of the river's cross section). The samples must be collected to represent the dredging period. That is, samples from an affected water parcel at each far-field station must be collected. Without consideration for time-of-travel between the remedial operations and the representative far-field station, false low values may be obtained and potentially large releases may go unidentified, even though samples will be collected daily under routine monitoring. (Note that this does not imply the requirement of strict time-of-travel sampling, only that the samples should be collected when it can be reasonably expected that dredging-related water quality impacts can be captured by sampling at each downstream far-field station.) The daily discrete routine monitoring will include the following variables:

- Total and Tri+ PCBs (whole water[17], congener-specific, low detection limits)
- Suspended solids
- Dissolved organic carbon (DOC)
- Organic carbon on suspended solids (weight loss on ignition on suspended solids, or similar measurement)
- Temperature
- pH
- Dissolved oxygen (DO)
- Conductivity

In situ probes are required for the following:

- Turbidity (continuous)
- Suspended solids size distribution via a particle counter (continuous at nearest far-field station only)

The discrete samples for PCBs are clearly required to document compliance with the far-field action level criteria and the Resuspension Standard threshold. The suspended solids, DOC, and organic carbon on suspended solids are all needed to support the interpretation of the PCB data, particularly when action levels are exceeded. The continuous reading parameters are needed as supporting information to confirm a minimal impact of

[17] Whole water samples require separation of dissolved and suspended matter fractions for separate extraction. Extracts may be combined into a single analysis.

dredging on water quality as well as to prompt additional PCB sampling in the event of a substantive suspended solids release.

The daily discrete monitoring parameter analytical methods must be sufficiently sensitive to avoid non-detect values at most stations and provide data that can characterize PCB concentrations during both routine and unusual conditions. In general, the analytical methods chosen for the monitoring program must meet or exceed the specifications of the methods used to develop the baseline water column concentration data. As discussed in further detail in the next section, the frequency and type of samples will be adjusted as action levels are exceeded. For example, the frequency of PCB sampling will be increased to as often as four times per day.

In addition to the daily discrete sample collection, two other forms of sampling will be included at these stations. Specifically, continuous suspended solids monitoring by means of turbidity and particle counters and the use of an integrating PCB sample (*e.g.*, an Isco sampler) will also be required. A surrogate relationship must be developed for suspended solids using a real-time measurement (turbidity or particle counter). These measurements will be conducted continuously and recorded on a regular basis for use within the same day. The surrogate relationship must be developed prior to Phase 1 and maintained throughout the program.

An integrating PCB sampler will be required as well to provide an alternate measurement basis for water column PCB concentrations. These sampling techniques provide a useful integration of water column loads over time and can be compared to historical measurements (to be collected during the remedial design) or simply to the prior months' data. The data from the integrating PCB sample can be used to document changes in PCB export from the dredging operations to the extent the changes occur in between daily discrete samples. The results can be compared to the more quantitative but instantaneous daily measurements of PCB concentration to generate a rough estimate of PCB transport.

More importantly, these samplers provide a long-term integration of PCB load, monitoring the relatively long periods of time between the daily sampling events. This information serves to confirm that river conditions as captured by the daily discrete samples are representative of general river conditions. These samplers do not provide real-time data but rather confirm that the discrete samples are providing a useful measure of average conditions. These samplers will be deployed in a manner similar to the regular water column points, (*i.e.*, multiple points in the river cross section will be sampled to obtain a representative sample where possible). These samples will be collected biweekly at the five Upper River main stem stations from Rogers Island to Waterford.

3.3.2 Near-Field Concerns

Local variation prevents useful monitoring of PCBs in the immediate vicinity (near-field) of the dredging operation. From the float studies conducted by GE in the late 1990s, it is clear that the PCB concentrations in the water column can increase greatly over relatively short distances from exposure to the contaminated sediments. Near-field downstream monitoring of the PCB concentrations cannot distinguish between the contribution resulting from resuspension during dredging and the contribution from the sediments. Additionally, the time lag between sample collection and the availability of PCB data (normally at least 24 hours, even with an accelerated turn-around time) preclude the use of PCB measurement as a real-time monitor of dredging operations. The ROD acknowledges that the water quality may be reduced in the short term, to allow the remediation to result in attainment of the long-term goals. Therefore, it is not useful to implementconcentration criteria in the near field, given the high spatial and temporal variability as well as the delayed receipt of information.

Using electronic sensors for continuous measuring of turbidity the near-field monitoring program will provide a real-time gauge of conditions around the dredging operation.

The near-field monitoring program is designed to provide a real-time measure of conditions around the dredging operation. It is designed recognizing that the far-field monitoring program cannot provide direct feedback to the dredge operators concerning the day-to-day operation of the equipment and engineering controls. For this reason, near-field monitoring will entail continuous measurement of turbidity through the use of electronic sensors (see Attachment F) to allow real-time response to changing conditions and dredge operator activities.

A surrogate relationship between turbidity and suspended solids must be developed and maintained throughout the program. Suspended solids samples will be collected daily to assess the predictive capability of the surrogate relationship. Suspended solids sampling only increases to once per three hours if the surrogate relationship fails to provide a sufficiently conservative estimate of the TSS concentrations. The criteria for the surrogate relationship are provided in Section 4.

The near-field monitoring program is not intended to provide quantitative measures of PCB loss from the dredging operations but rather to provide a more sensitive qualitative measure of the possible impacts of various dredging activities. These results will be used in coordination with far-field turbidity, suspended solids, and PCB monitoring so that acceptable levels of near-field turbidity can be developed from the net effects observed downstream.

The near-field monitoring program will include suspended solids and turbidity monitoring both upstream and downstream of the dredging operation, so that dredging-related turbidity and associated suspended solids can be identified. Sensors will be deployed at specific distances downstream of the dredging operation that have been determined based on information available in the literature as well as on results of the near-field modeling analysis described in Attachment D. In addition to direct sensor measurements, daily discrete particle counter suspended solids measurement will also be collected *in situ* to provide analytical confirmation of the sensors.

The near-field monitoring program provides the best opportunity to obtain real-time results that can be used to guide the dredging operations and to identify activities that may result in unacceptable releases of PCBs from the sediments. While PCB monitoring is the ultimate measure of downstream impacts, the real-time turbidity and suspended solids monitoring provides the best means of minimizing suspended solids and PCB release.

Real-time turbidity and suspended solids monitoring provides the best means of minimizing suspended solids and PCB release.

While the use of turbidity or suspended solids monitoring provides valuable real-time data, there are some issues that need to be considered in the design of the monitoring program and interpretation of the data. Besides the straightforward issues of sample accuracy and representativeness, the installation of backfill concurrent with the dredging operation may serve to confound the turbidity and suspended solids signals. To the extent that backfill creates large amounts of turbidity, it is possible that the contribution of dredging-related turbidity or suspended solids may be indiscernible. The expected close proximity of dredging and backfill operations will make it difficult to estimate the suspended solids load upstream of dredging but downstream of the backfilling. Thus, measurement of the local impact of dredging by suspended solids monitoring may be compromised. This is addressed to the extent possible by placing a suspended solids and turbidity monitoring station just upstream of each dredging operation. It is, however, expected that backfilling operations will not always coincide with dredging, which would simplify the suspended solids monitoring during these intervals.

Further refinement of the near-field and far-field suspended solids criteria is anticipated at the completion of Phase 1, and possibly during Phase 1 if appropriate. Pending the results of Phase 1, suspended solids criteria may be developed that may require engineering evaluations or improvements. (As currently constructed, the Resuspension Performance Standard only requires an engineering action in response to PCB-based exceedances.)

In summary, both PCB and suspended solids monitoring have limitations that affect the usefulness of the data. For PCBs, the time lag between sampling and the availability of the data as well as the baseline release of PCBs limit the measurement sensitivity. For suspended solids, the near-field heterogeneity, the sensitivity of the surrogate measurement and the impact of backfilling resuspension potentially confound the measurement. Nonetheless, these measures taken together can provide a rigorous basis on which to monitor downstream transport and compliance with the Resuspension Standard.

3.4 Data Quality Objectives

The monitoring plan for the Resuspension Performance Standard is summarized in Tables 1-2, 1-3 and 1-4. The main objectives of the monitoring plan are described in the following subsections, along with the techniques intended to satisfy these objectives. This analysis represents an initial analysis of the DQOs that will undergo subsequent refinement during preparation of the quality assurance plans for dredging-related monitoring. As such, it is expected that the monitoring requirements developed for the standard represent a minimum level of monitoring and that additional sampling beyond these requirements will be needed to completely understand the nature of any dredging-related release.

These monitoring requirements, therefore, are primarily intended to document compliance with the various criteria of the Resuspension Standard. Special studies, as outlined in Section 4.0 will provide information to verify assumptions made about the behavior of the contaminant releases due to dredging (*e.g.,* PCB dissolution, suspended solids settling and dissipation). Information collected to verify these assumptions during the Phase 1 period should serve to improve the monitoring program during Phase 2 in several ways. The Phase 1 data should permit identification of the most effective monitoring locations and monitoring techniques as well as those that are not useful. This information may also permit a reduction in the frequency and complexity of monitoring during Phase 2.

Subsections 3.4.1 to 3.4.3 contain a discussion of the main DQOs and a discussion of the sampling approaches needed to satisfy each objective. Subsection 3.4.4 provides a summary of the analyses that confirm the adequacy of the sampling frequencies required as part of the routine and non-routine monitoring programs. More detail is provided in Attachment G. These analyses, which conform to USEPA methods for assessing statistical uncertainty (USEPA, 2000f), cover only routine monitoring and the minimum levels of contingency monitoring as defined in the Resuspension Standard. Additional monitoring related to the required engineering studies at the Concern and Control Levels (as well as exceedance of the standard threshold) may be required, depending on the anticipated cause of the exceedance. These may be conducted as a part of the engineering evaluations. The design of these additional monitoring programs may occur during the remedial design period. It is also likely that monitoring plans will need to be developed by the contractor during the dredging operation in response to observations made at the time.

A particular limitation to the analysis summarized in subsection 3.4.4 is lack of information on the variance of river conditions in response to dredging-related releases. Little data exist on which to develop the estimate of variance. As a result, the variation of baseline conditions was used as a means to estimate the variance for dredging operations. These estimates for sampling requirements and the associated error rates will require review once additional data become available during Phase 1.

3.4.1 Objectives for Far-Field Monitoring in the Upper Hudson

The far-field monitoring program in the Upper Hudson River addresses several DQOs. This program is the primary monitoring effort for the protection of public water supplies and for determining the magnitude of long-term PCB releases. Following the statement of each data quality objective is a discussion of the sampling techniques to be used to satisfy the objective.

3.4.1.1 Objective I

Provide a set of data to demonstrate compliance with the Total PCB concentration components of the Resuspension Standard (*i.e.*, the 350 ng/L criterion for the Control Levels and the 500 ng/L criterion for the standard threshold).

- Dredging-related operations are expected to occur throughout the Upper Hudson between Fort Edward and Waterford. Hence, dredging-related PCB releases may occur over the entire region as well. In particular, while the majority of dredging is focused north of Schuylerville, boat traffic and other operations are expected to occur downstream of Schuylerville. Thus, PCB concentrations must be monitored throughout the Upper Hudson River. Additionally, PCB release due to dredging is not expected to be constant with time but is expected to vary substantively over time. Thus, discrete grab samples collected at one station at one point in the day may miss more substantial release events occurring at other times. As the river carries these releases, natural mixing and dispersion will serve to homogenize PCB concentrations to some degree, spreading them out and making it easier to collect representative samples at locations farther downstream. Multiple stations, therefore, provide the ability to capture conditions representing a longer period of time.

  Note that the desire to obtain many samples from the river to characterize conditions must be tempered by the availability of laboratories to analyze the samples. For this reason, sampling under routine conditions (expected to be the majority of the conditions while dredging) will only require daily samples from the far-field stations plus a limited number of longer-term integrated samples (see Table 1-2). This consideration also recognizes the need to obtain and analyze samples sufficiently rapidly to address Objective II below. An alternative to these discrete samples is the collection of daily composite samples, integrated over a 24-hour period at each station. These samples still require the collection of a cross section composite for each day. Additional sampling will be required if 24-hour composites are collected when certain resuspension criteria are exceeded.

- It is necessary to correctly characterize the PCB concentration throughout the river cross section, recognizing that both baseline and dredging-related releases create heterogeneous PCB concentrations. This has been extensively demonstrated by the paired sample data

Because both baseline and dredging-related releases create heterogeneous PCB concentrations, It is necessary to correctly characterize the PCB concentration throughout the river cross section.

collected at TID-West and TID-PRW2. For this reason, at least five points are required at each sampling station, based on equal width or equal discharge considerations as given by USGS guidance (USGS, 2002). Multiple points are required for discrete samples as well as the alternative daily composite samples.

- To support the use of discrete samples as representative of mean river conditions, it is also necessary to obtain integrated samples. These samples will serve to demonstrate compliance with the standard during periods between discrete samples. Integrated samples will cover two-week intervals during routine monitoring, providing a longer perspective on PCB transport and concentration with relatively little increase in the total number of PCB analyses. Rapid turnaround of results is not needed for the integrated samples because these samples take longer to collect. The resulting PCB average concentrations provide confirmation of data obtained from daily discrete samples. As such, these results are needed during Phase 1 to provide supporting data for the discrete samples. If the viability of the discrete sampling program is confirmed, these samples may be dropped or greatly reduced during Phase 2.

- Samples must be collected at sufficient frequency to provide a reasonable statistical certainty that conditions are in compliance with the Resuspension Standard criteria. Higher statistical uncertainty is acceptable when concentrations are well below the standard criteria. As the action levels and the standard threshold are approached, sampling frequency must be increased to provide greater certainty that conditions are still in compliance. In particular, it is important to minimize the false negative error, the error of accepting conditions to be in compliance when in reality they are not. The issue of sampling frequency is discussed in subsection 3.4.4 and Attachment G more extensively.

- Analytical methods for the monitoring program must meet or exceed the specifications for the baseline monitoring program to provide sufficient precision, sensitivity, accuracy, and representativeness. The monitoring results from the baseline program are a basis of comparison for the Resuspension Standard and must be consistent.

3.4.1.2 Objective II

Provide a means to rapidly assess water column Total PCB levels so that the USEPA can advise public water suppliers when water column concentrations are expected to approach or exceed the federal MCL (*i.e.*, 500 ng/L) during the remediation.

In this manner, public water suppliers can take contingency actions, if needed, to maintain safe water for their users. Appurtenant to this objective, determine the relationship of dredging-related PCB contamination at the upstream far-field stations (TI Dam and Schuylerville) to that at the downstream far-field stations (Stillwater and Waterford) in order to use the far-field stations near the remediation as predictors of downstream concentrations entering the public water intakes.

There are several aspects of the monitoring plan that are required to achieve these closely related objectives. These are described below.

- Measurements of PCB concentrations at all Upper Hudson far-field stations are needed on a daily basis to identify possible exceedances of the standard threshold and any action level criteria. These data satisfy both components of this objective, since the data will document the PCB concentrations and also serve as a database to resolve the relationship between upstream and downstream PCB concentration increases related to dredging.

- Reduced turnaround time for PCB samples from the two far-field stations nearest to the dredging operations is required. During Phase 1 these stations will probably be TI Dam and Schuylerville, although the Phase 1 dredging area has not yet been defined. The results from sampling at these stations will be used to assess the need to warn the public water supplies that the concentrations entering the intakes may be elevated. The travel time between remediation activities in River Sections 1 and 2 and the Waterford public water supply intakes is generally at least two days, although during high flow events, the travel time is shorter. Thus, in order to have information from the primary dredging areas in time to provide a warning to the downstream intakes, a turn-around time of 24 hours or less is required for the samples obtained from the two nearest downstream far-field stations. (Note that because the turn-around time for PCB analysis is 24-hours, it is also important to develop a real-time indicator of elevated contaminant levels.)

- While actual PCB measurements provide the most certain basis for assessing PCB loads and concentrations, these cannot be obtained in real-time. Resuspension of contaminated sediment is thought to be the primary mechanism of dredging-related contamination release. When verified, suspended solids monitoring provides one of the best means of warning the public water supplies of potential exceedances, since it provides the longest lead time between knowledge of the release and its arrival at the downstream intakes.

  Additionally, as the dredging operations move farther downstream, suspended solids monitoring will provide the only real-time data for the protection of downstream impacts. Specifically in River Section 3, there will be insufficient time to collect, analyze, and evaluate a PCB sample and still warn the downstream intakes. As a result, the standard requires that a surrogate measure of suspended solids concentrations (turbidity or laser particle counter) be developed and maintained throughout the remediation. Samples will be collected once a day for suspended solids analysis to provide confirmation of the surrogate results. Each week, the measured suspended solids results will be compared to the predicted values to determine if the surrogate is providing sufficiently accurate results, based on a statistical analysis. (See Section 4 for details of these special studies.)

- Frequent suspended solids measurements (every three hours) will only be required when the surrogate measurements for suspended solids are not providing a conservative measurement. A modified method for suspended solids analysis will be specified to permit a short turn-around time (three hours). Co-located samples will be collected for both the modified method for suspended solids and the unmodified method that is based on ASTM 3977-97 once a day as to assess the accuracy of the modified method.

- At the far-field stations, monitoring for suspended solids via a surrogate is conducted on a 24-hour-per-day basis.

3.4.1.2.1 Objective III

Provide a set of data to demonstrate compliance with the Total PCB load components of the Resuspension Standard (*i.e.*, 300 g/day and 600 g/day).

- As stated in subsection 3.4.1.1 Objective I, dredging-related operations are expected to occur throughout the Upper Hudson between Fort Edward and Waterford, increasing PCB loads as well as concentrations. PCB loads, however, represent a longer-term concern since the associated impacts will take longer to occur and thus require a sustained level of loading in order to occur. A high frequency of monitoring in Phase 1 can provide an opportunity to identify substantive increases in load soon after occurring so that the root cause can be identified and long term impacts avoided. To this end, the monitoring frequency required to satisfy the concentration criteria is expected to also satisfy this objective.

- Since PCB loads over time are the primary concern of this objective, it is desirable to obtain integrative samples for this objective as well. For this reason, integrative samples will be obtained at the four main far-field stations during Phase 1, as discussed under Objective I. These will provide confirmation of the initial conclusions drawn regarding PCB loads based on the more frequent discrete samples.

- Data on river discharge is also needed to address load considerations. Data from the USGS stations at Fort Edward and Waterford will be used to this end. In the event that the USGS discontinues these stations, data on flow must be obtained by an alternate means. Additional data on meteorological conditions must be obtained to supplement the USGS data and permit an accurate representation of flows at the stations not monitored by the USGS.

- Sample collection must be timed to capture the impacted water column. If samples were collected each day from the nearest far-field station at the onset of the operations, it is unlikely that the water collected would show the dredging-related impacts. The plume will

Sample collection must be timed to capture the impacted water column.

widen and lengthen as it travels downstream, making it more likely that the downstream stations will capture dredging-related impacts. (This is not, however, a time-of-travel sampling. Although the parcel of water sampled must be impacted, the same parcel of water need not be tracked as it passes down the river.)

- Equal discharge increment (EDI) or equal width increment (EWI) sampling as defined by USGS will be required. This type of sampling method is required to capture a representative cross-sectional sample. A single center channel station will not be sufficient, because extensive natural mixing across the channel is unlikely in most of the Upper Hudson and plumes confined to the shoreline by river hydrodynamics will not be accurately represented, resulting in low-biased results.

3.4.1.3 Objective IV

Determine the primary means of PCB release via dredging-related activities. (Verify that dissolved phase releases are minimal as estimated by modeling and that the primary mechanism of release is suspension of sediment.)

- During the public comment period on the Hudson River ROD, concerns were raised that dredging of PCB contaminated sediment could release a substantial amount of dissolved-phase PCBs. Calculations to determine whether and how such a release could occur (Attachments C and D) have indicated that this scenario cannot occur and that the primary release mechanism would be resuspension of contaminated sediment. This mechanism would be accompanied by an increase in suspended solids concentration and could be tracked in the near field.

  Dredging is not expected to release substantial amounts of dissolved-phase PCBs directly. A special study will assess the primary release mechanism in the vicinity of the dredging operation.

  Though convincing, the calculations done to determine the primary mechanism of release need to be verified in order to be certain that the goals of the ROD can be achieved (long-term recovery of the river, protection of the environment and human heath). This will be accomplished by a special study, which will characterize dissolved-phase and suspended-phase Total PCB concentrations in the vicinity of dredging operations. Several of these studies will be conducted to characterize the releases for various concentration ranges, sediment types and dredging equipment. Samples will be collected daily for a week at each selected location to provide a sufficient number of samples given the high degree of variability in the near-field conditions. More details of this special study are provided in Section 4.

  The objective of the special study is to determine whether there is a substantial dissolved-phase release from the remedial operations consistent with that estimated by the USGS at the Fox River site. The study will not be designed to quantify a low-level dissolved-phase release; hence, it will not be necessary to extensively characterize the baseline conditions in these areas. A station upstream from the remedial operations will be monitored for comparison.

Additional parameters will be required to aid in the interpretation of the split phase data. Dissolved organic carbon, suspended organic carbon, suspended solids, turbidity, and temperature provide an indication of the distribution of dissolved-phase and suspended-phase PCBs. These parameters will also be measured for the discrete samples collected during routine monitoring and contingency monitoring. In this manner, changes in these supplemental parameters may help identify the nature of the mechanism responsible for the PCB release throughout Phase 1, assuming equilibrium has been reached.

3.4.1.4 Objective V

Determine the baseline Total PCB levels entering River Section 1 from upstream sources.

- PCBs entering River Section 1 should be identified so as to differentiate these additional concentrations from the releases occurring downstream. Based on monitoring data from the past five years, PCBs have been at non-detect or low concentrations entering River Section 1. However, changes in upstream conditions such as construction at the source areas could result in higher PCB concentrations entering the TI Pool. Monitoring at Bakers Falls and Rogers Island for PCBs will be required to identify such situations. If the contribution from upstream sources were to increase, the Bakers Falls and Rogers Island results should document this occurrence and provide a basis to adjust the dredging-related load contribution.

  This information will help to avoid an unnecessary enforcement of the engineering or monitoring contingencies of the standard and should be done on a case-by-case basis. The sampling frequency will be once per week at Bakers Falls and once per day at Rogers Island. With USEPA's approval, the frequency at Rogers Island may be further reduced if these concentrations are shown to be consistently low relative to dredging-related releases.

- Both Bakers Falls and Rogers Island stations are needed for this purpose. An important assumption in the ROD was the continued reduction of the releases from the GE Hudson Falls facility. Differences in PCB concentration and load between these two stations will be used to document this process. In the event that these data are collected as part of other remedial activities upstream of Rogers Island, these data do not have to be duplicated by the dredging-related monitoring. However, these data must meet the data quality objectives defined here and in the subsequent quality assurance plans issued for the Resuspension Standard.

- Detection limits for Total PCBs for these data must achieve equal or better reporting limits as those achieved for the remedial design baseline monitoring program, approximately 4.0 ng/L for an eight-liter sample. Lower reporting limits (*i.e.,* less than 4 ng/L) will be required if sample results at Rogers Island routinely fall below the reporting limit since accurate quantitation of this load is an integral part of the long-term monitoring program.

- Additional data will be required to aid in the interpretation of downstream data. Baseline levels of DOC, suspended organic carbon, suspended solids, and temperature are needed to characterize the changes in these parameters that may be caused by dredging-related activities. Dissolved oxygen measurements will be taken at Rogers Island for the same purpose.

- Since baseline conditions should not change in response to dredging-related releases, the frequency of baseline monitoring does not increase in response to action level or threshold exceedances.

Baseline conditions should not change in response to dredging-related releases; thus baseline monitoring frequency does not increase in response to action level or threshold exceedances.

3.4.1.5 Objective VI

Determine ancillary remediation-related effects on the river (*e.g.*, barge traffic-related resuspension, spillage during transit or off-loading of sediment) that may occur in areas that are not captured by the nearest representative far-field station.

During Phase 1, the remediation will probably be limited to the TI Pool. Once the material is dredged it will be conveyed to another location for further processing and shipping to a landfill. This destination may not be in the TI Pool, resulting in transport of contaminated material throughout stretches of the Hudson River by barge or pipeline. To verify that the transport of material is not causing the release of PCB contamination to an extent that would cause exceedance of the resuspension criteria, sampling will be required at each Upper Hudson River far-field station (except Bakers Falls) at least once per day.

3.4.1.6 Objective VII

Verify that the water column PCB concentrations developed from the grab samples adequately characterize the average concentration.

- Discrete grab samples will be used for comparison to the PCB flux and concentration resuspension criteria. The Resuspension Standard requires that samples must be timed to capture the impacted water column, increasing the likelihood that the samples will be representative of the dredging-related impacts. As described in subsection 3.4.4, the sampling frequency is sufficient to compare the results of the analyses to the resuspension criteria with confidence, but this analysis is based on an assumption of the variability of the water column concentrations. This estimate of variability is derived from the baseline conditions, which do not include the added variability of the dredging-related releases. This added variability could change within a day as different operations are completed and different dredge operators are employed.

To verify that the grab samples are sufficiently indicative of average river conditions, integrating samplers are required for deployment periods ranging from two weeks under routine monitoring to one day under Control Level monitoring. Integrating samplers cannot entirely replace the required grab samples at TI Dam and Schuylerville, even if all other DQOs are met by this sampling method, because it will be important to have some measure of the upper and lower bound concentrations that are occurring in the river as well as the average condition near the remedial operations.

- Integrating samplers are required for daily measurements in place of discrete grab sampling at Stillwater and Waterford at the Concern and Control Level monitoring as well. This sampling method is used because of the concern that the water column concentrations are approaching the MCL. Integrating samples are used here instead of multiple grab samples to reduce the overall number of PCB analyses while still obtaining data on PCB concentrations over a 24-hour period.

3.4.1.7 Objective VIII

Confirm the exceedance of the action level criteria as well as the standard criterion.

- Sampling frequency must be increased to verify exceedances of the resuspension criteria. At lower levels of exceedance, the consequences of error in deciding whether the resuspension criteria have been exceeded are less serious than at higher levels of exceedance. Hence, a higher level of decision uncertainty is acceptable at exceedances involving the lower action levels. At the Evaluation Level, the concern is adherence to best practices and long-term PCB release impacts, concerns that do not require a rapid (*i.e.*, 24-hour) response. At PCB concentrations close to or above the Resuspension Standard, public water supplies could be impacted and a shutdown of the dredging operations may be required. Thus, a greater level of certainty is required when the consequences are greater. This is the primary reason for requiring increased frequency of sampling in the standard. The development and level of certainty provided by the various sampling regimes are further discussed in subsection 3.4.4.

- An increase in monitoring frequency will be required as a contingency at the two representative far-field stations during Phase 1. These stations provide the best opportunity to document river conditions in response to dredging-related releases and also provide a warning to downstream public water supply intakes. With the uncertainty related to dredging-related releases, the second station will confirm the observations of the nearest far-field station and thus provide a sound basis for whatever response actions are required.

- Monitoring of the downstream far-field stations (Stillwater and Waterford) for PCBs will be changed to daily integrated sampling to capture the average concentrations that would be entering the public water supply, while PCB concentrations collected from stations nearer to the remediation may be approaching the resuspension standard threshold. Data from the integrated far-field samples provide further subsequent confirmation of the estimated concentrations based on conditions closer to the dredging operations.

  Results from these downstream stations can be used to refine the means of predicting the PCB concentrations that will enter the public water supplies based on the concentrations measured nearer to the remediation. These results will indicate the degree to which the PCB concentrations dissipate as the water column passes downstream. The switch from a daily discrete sample to an integrated sample reflects the need to characterize the entire day's water conditions while minimizing the number of samples collected, so that results can be made rapidly available and interpreted.

3.4.1.8 Objective IX

Confirm Alternate Monitoring Programs.

The monitoring program outlined in Tables 1-2, 1-3 and 1-4 has been constructed around the standard. It may be possible to employ alternate monitoring techniques. However, the ability of alternate monitoring programs to achieve the data quality objectives must be demonstrated. Modifications to the resuspension criteria and required actions if exceeded may be required as well in response to the changes. This will be the subject of a special study. Details are provided in Section 4.

3.4.1.9 Objective X

Measure the parameters with precision, accuracy, representativeness, comparability, **completeness and sensitivity that is equivalent to the baseline monitoring program specifications**.

- Analytical methods for the monitoring program must meet or exceed the specifications for the baseline monitoring program to provide sufficient precision, sensitivity, accuracy, representativeness, comparability, completeness and sensitivity. The monitoring results from the baseline program are a basis of comparison for the resuspension standard and must be consistent.

- Sample collection and sample handling must be consistent with the approach taken during baseline.

- As verification of these methods it will be necessary to have performance evaluation PE samples. The purposes of these samples will be to determine that the results for multiple laboratories are consistent in terms of both accuracy and precision. The PE samples will be used to verify that the congener distribution identified among the laboratories is consistent.

An exception to this objective will be the specification of a modified analytical method for suspended solids that will permit the results to be available in three hours.

3.4.2 Objectives for Near-Field Monitoring in the Upper Hudson

3.4.2.1 Objective XI

P**rovide a real-time indication of suspended solids release in the near field.**

A real-time indication of the amount of suspended solids in the water column in the near field will aid the dredge operators in minimizing the release of suspended solids and associated PCBs during the remediation. This monitoring will also provide the earliest evidence for a substantive PCB release and allow further response by direct PCB measurements downstream. To this end, turbidity monitors will be placed around each dredging or debris area undergoing remediation. Information from these monitors will provide continuous feedback to the operators, allowing real-time adjustments to be made to the operations as needed.

3.4.2.2 Objective XII

Determine the amount of suspended solids released by the remedial operations to provide an indication of PCB export.

- Calculations presented in Attachment C indicate that the primary release mechanism of dredging-related contamination is resuspension of contaminated sediment. Thus, an increase in suspended solids should correlate with an increase in PCB contamination. The standard requires that a surrogate relationship be developed for suspended solids concentrations in the near field and maintained throughout Phase 1. Samples will be collected daily for suspended solids analysis as a means of assessing the surrogate relationship. Samples will be collected twice daily for suspended solids analysis if there is an exceedance of the suspended solids criteria. This increase in susppended solids sampling is limited to the noncompliant nodes. If the continuous reading surrogate (*e.g.*, turbidity) fails to adequately predict suspended solids concentrations, samples will be collected every three hours for suspended solids analysis until an adequate surrogate relationship is developed. More details are provided in Section 4 on this special study.

- Near-field sampling is limited to the hours of operation, with some pre- and post-dredging sampling.

- Exceedance of the near-field criteria prompts limited far-field sampling for PCB analysis (and supporting analyses) at the nearest downstream representative far-field station. These data, combined with the results of the far-field PCB analytical results, can be used to develop a relationship between suspended solids and PCB concentrations, and also provide a means of adjusting the suspended solids-based resuspension criteria, although a predictive correlation is not expected due to the heterogeneity of the sediment concentrations.

3.4.2.3 Objective XIII

Verify that the NYSDEC surface water quality regulations are not violated during the remediation.

NYSDEC has water quality standards for pH and dissolved oxygen (DO). At both the near-field and far-field stations, pH and DO will be monitored discretely each time a sample is collected. These parameters, plus conductivity, will also provide a measure of quality assurance for the data collected.

3.4.3 Additional Monitoring Objectives

3.4.3.1 Objective XIV

Monitoring in the Lower Hudson: Determine the extent of short-term impacts to the Lower Hudson River and examine the effect of Upper Hudson dredging activities on Lower Hudson PCB concentrations.

- The monitoring program for the Lower Hudson is designed to measure the short-term impacts to the freshwater portion of the river (previously referred to as the Mid-Hudson River during the Reassessment) resulting from the remediation. The sampling requirements in the Lower Hudson are not designed for comparison to the resuspension criteria. This is addressed by the frequent sampling at Waterford, which will be extrapolated to conditions downstream.

  Requirements for additional monitoring at the public water supply intakes will be prepared as part of the community health and safety plan (CHASP) currently under public review. The Lower Hudson stations are intended to characterize general water column conditions in response to elevated PCB concentrations and loads originating from dredging. These stations consist of a single center channel location that can be readily reoccupied. Cross sectional sampling is not required, since flow is not unidirectional and thus flux cannot easily be estimated.

- The frequency of sampling is increased in the Lower Hudson in response to greater loads and concentrations in the Upper Hudson, *e.g.*, when the concentration at Troy is expected to exceed 350 ng/L Total PCBs. This is done to examine Lower Hudson conditions in response to these loads, part of documenting recovery of the river.

> *The monitoring program for the Lower Hudson will measure short-term impacts to the freshwater portion of the river (referred to as the Mid-Hudson River during the Reassessment) resulting from the remediation.*

3.4.3.2 Objective XV

Verify the selection of the monitoring locations.

The locations of the far-field and near-field monitoring stations were selected based on several considerations, including near-field and far-field monitoring, ease of access, and level of planned dredging activities. The suspended solids and PCB analyses will be used to verify that these locations are appropriate. Monitoring of the far-field station less than one mile from the remediation will be required even though the PCB measurements will not be used for comparison to resuspension criteria during Phase 1. These results will determine whether the station is heavily impacted by the nearby remediation and will validate the requirement that far-field stations be more than one mile from the remediation. (Monitoring for compliance with the far-field net suspended solids resuspension criteria will be required each day, no matter how close the remediation is to the far-field stations.)

3.4.3.3 Objective XVI

Non-Target Area Monitoring: Determine the degree and extent of contamination resulting from the remedial operations downstream from the target areas.

- A special study will be conducted to measure the amount of resuspended material that has settled in the immediate downstream areas and is a potential source of future contamination of the water column and downstream surficial sediment. The primary DQO for this study is to determine the extent of contamination in terms of spatial extent, concentration and mass of Tri+ PCB contamination deposited in non-target near-field areas downstream from the dredged target areas.

- This study is needed because contaminated material may be disturbed by the remedial operations and move downstream along the bottom of the river, only to be identified by the water column monitoring during the next high flow event of sufficient force to transport the material. The near-field suspended solids monitoring is not conservative with regard to this issue because these criteria are based on the assumption that a single dredge meets the full production, when it is likely that several dredges will be required. Resuspension due to several dredges can theoretically create more local deposition because of settling between dredge operations. The near-field suspended solids criteria were established based on a single large plume since this approach is conservative for PCB dissolution and thus maximum PCB transport. Therefore, it is not sufficient to assume that compliance with the resuspension criteria means that the loss from the remedial operations will not create an unacceptable degree of contamination downstream.

- To address this objective, a special study will be conducted to measure the amount of resuspended material that settles in the downstream areas and that may act as a potential source of future contamination to the water column and downstream surficial sediment. Each study areas will be located downstream of a dredging area and will be approximately five acres in size. Samplers (*e.g.*, sediment traps) will be installed at multiple locations prior to the start of the dredging in the area under study. The exact number of locations per study area will be determined as part of the sampling plan development. At each sample location two or more co-located sediment traps will be deployed. Sediment accumulated in one of the samplers at each location will be collected and sent for analysis once the dredging in the area is completed, including any redredging attempts. Sediment accumulated in the second set of samplers will be collected at a higher frequency (perhaps weekly) to examine the relationship between various dredging operations and sediment accumulation.

- The study will be conducted at several target areas to determine the degree and extent of contamination over a range of conditions. The selected areas must represent a range of sediment textures, contamination levels and remedial equipment.

- Measurement techniques will include suspended solids mass, PCBs, and other pertinent variables. The techniques employed will meet or exceed the specification for the analytical and sampling methods with the SSAP.

3.4.4 Statistical Justification of the Sampling Frequency

The adequacy of the sampling frequencies required as part of the routine monitoring programs was examined using the USEPA defined methods for assessing statistical uncertainty (USEPA, 2000). The analyses cover only routine monitoring and the minimum levels of contingency monitoring as defined in the Resuspension Standard.

The final sampling requirements for the standard were developed using USEPA's Decision Error Feasibility Trials Software (DEFT) (USEPA, 2001), a program to estimate sampling requirements based on a project-specific error rate. The results of this analysis are presented in Table 3-2.

As defined in DEFT:

- A *false acceptance* decision error occurs when the sample data lead to a decision that the baseline condition is probably true when it is really false.

- A *false rejection* decision error occurs when the limited amount of sample data lead to a decision that the baseline condition is probably false when it is really true.

- The *gray region* is a range of true parameter values within the alternative condition near the action level where it is "too close to call."

The analysis of the various criteria and acceptable gray region around each criterion yielded the results shown in Table 3-2. The table is organized by measurement type (*i.e.*, PCB and suspended solids). False acceptances were minimized because this is the more serious error. For all criteria except the confirmation of the 500 ng/L exceedance, the null hypothesis assumed that river conditions were in compliance.

Decisions that are more critical generally require a large number of samples and have greater certainty than the less critical decisions.

In general, decisions that are more critical (*e.g.*, confirmation of exceedance of the Resuspension Standard which requires shut down, or exceedance of the Control Level, which requires intense monitoring and engineering responses) require a large number of samples and have greater certainty than the less critical decisions. For the suspended solids measurements, it is clear from this analysis that the implementation of a continuous monitor capable of estimating suspended solids concentrations will be needed to have a reasonable amount of certainty in these decisions. The low level of certainty is tolerable only because any decisions made as a result of exceedance of the suspended solids will be confirmed by measurements of PCB concentrations in the impacted water column.

Table 3-2 shows that the higher level of sampling associated with the higher action levels and the Resuspension Standard yield low false error rates, as expected, reflecting the need to be accurate before taking costly actions or improvements. In some instances, the false rejection rate is fairly high, indicating that additional sampling may be unnecessarily triggered. However, this represents a protective approach from the perspective of the safety of the public water supplies. Additionally, the higher monitoring rates will quickly confirm the need to remain at the action level thought to be exceeded.

Higher error rates are estimated in transitions from routine conditions to the Evaluation and Control Levels, reflecting the relative low sampling rate required for routine sampling. Also shown in the table is the one-week confirmation result (*i.e.*, the error rate for the combination of one week of routine monitoring and one week at the action level). In each instance the false acceptance error is brought below 5%, thereby confirming the need to sample at the higher rate or indicating that sampling at the routine rate may be resumed.

The results for monitoring requirements for exceedance of the standard demonstrate the need for the intensive sampling specified. In this instance, the river is assumed be in exceedance of the standard. Four additional discrete samples (Table 3-2) do not provide sufficient certainty given that the next day's decision will involve the temporary halting of the dredging operations, a costly choice. However, by collecting hourly composites, the power of the same four analyses is greatly improved and the 5% false acceptance rate is attained. Table 3-2 also shows the results for the long-term integrative samples. These samples will serve to confirm the results of daily routine monitoring or to demonstrate the need for more frequent sampling. The results assume the automated collection of eight samples per day over a one- to two-week period.

The results for suspended solids illustrate the need to use a continuous sampling system such as a turbidity probe. In the lower portion of the table, results for the discrete sampling program are compared with those that can be achieved with a continuous probe recorded once every 15 minutes. In almost all cases, the continuous reading probe provides more than an order of magnitude of improvement in the expected error rate. Better rates can be achieved with the continuous probes by simply recording more frequently.

It has been demonstrated that continuous reading turbidity probes provide more than an order of magnitude of improvement in the expected error rate.

Note that this analysis does not consider any uncertainty introduced by use of a probe over discrete samples. Nonetheless, given a semi-quantitatve relationship between the probe and actual suspended solids levels, it is highly likely that the probes will provide a substantial reduction in the expected error rates for suspended solids monitoring, thereby reducing unnecessary additional PCB sampling prompted by a false indication.

Table 3-3 contains the following information related to use of the automatic sampler:

- Summary of the various criteria
- Associated gray region
- Sampling frequency required by the resuspension standard
- False acceptance and false rejection levels for Total PCB sampling requirements when the automatic sampler is used

Using the automatic sampler, the error rates for most of the sampling requirements are less than 1%. The highest error rate was about 2% for the false rejection of the sampling requirement from evaluation to control level. However, this value is still below 5% error rate. This analysis shows that, theoretically, the power of the sampling program for Total PCBs using automatic sampler is greatly improved. In actuality, an alternate monitoring program that is primarily based on sample collection via automatic samplers will only be as good as the implementation. There are numerous challenges associated with such a program that must be carefully worked through during a special study. See Section 4 for more information.

3.5 Summary of Rationale

The rationale for the performance standard for PCB loss due to resuspension has its basis in the goals outlined in the ROD (USEPA, 2002a). The need to protect downstream fish and fish consumers and the need to protect public water supply intakes define the objectives for the standard. Action levels were derived from consideration of ARARs for the site and RAOs from the ROD, as well as the ability to detect a net increase in PCB loads. These criteria were shown by modeling analysis to produce little change in downstream fish tissue recovery, further supporting their use as action levels.

The rationale for the performance standard for PCB loss due to resuspension has its basis in the goals outlined in the ROD.

Specifically, PCB releases commensurate with 500 ng/L Total PCB had no substantive impact on the fish recovery once dredging operations were completed.

Ultimately the RAO concerning the transport of PCBs to the Lower Hudson provided the lowest upper bound on the acceptable amount of PCB loss (*i.e.,* 600 g/day Total PCB or 650 kg Total PCB over the entire period of dredging). Additional action levels were needed to provide a tiered series of action levels with an increasing amount of contingencies as the action levels are exceeded. The criteria, monitoring requirements, and engineering contingencies are all designed with the intention of identifying and correcting minor problems in the dredging operation while keeping the dredging operation functioning smoothly and steadily.

Due to the variable conditions within the river over time, the Total PCB concentrations may be greater than 350 ng/L Total PCBs, even though the load-based criteria are not exceeded. This results from elevated baseline conditions and is most likely to occur in May and June. The concentration-based action levels will govern, since these action levels are intended to provide short-term protection for the downstream public water supplies and therefore represent the more protective criteria in these instances. It is also possible that the suspended solids criteria may indicate elevated PCB concentrations that are not verified by subsequent PCB sampling and analysis. This is recognized in the standard by requiring only additional sampling of the impacted water column at the nearest representative far-field station for comparison against the resuspension criteria as outlined in subsection 4.1.

4.0 Implementation of the Performance Standard for Dredging Resuspension

The Resuspension Performance Standard consists of the standard threshold and associated action levels, monitoring requirements and engineering requirements. The implementation of the action levels is described in subsection 4.1. Compliance monitoring requirements including measurement techniques, monitoring locations and other specifics are described in subsection 4.2. The procedures to revert to lower action levels or routine monitoring are presented in subsection 4.3 The requirements for the special studies are defined in subsection 4.4. For engineering contingencies, the engineering evaluations, technologies for controlling releases that may be implemented, and the requirements of the standard regarding engineering contingencies are described in subsection 4.5. Reporting requirements are described in subsection 4.6.

Flowcharts depicting the implementation of the Resuspension Standard are provided in Figures 4-1, 4-2 and 4-3 for the near-field suspended solids criteria, far-field Total PCBs and far-field suspended solids. These flowcharts are a simplified depiction of the interaction between the three aspects of the standard: action levels, monitoring and engineering controls. To fully implement the Resuspension Standard the specifications provided throughout this document must be upheld.

4.1 Resuspension Criteria

This subsection contains details of the implementation of the standard. Table 1-1 contains the requirements and criteria of the standard in tabular form. Implementation of the Resuspension Standard will necessarily require monitoring for the parameters of concern. Daily measurements of suspended solids and PCB concentrations can then be compared with the appropriate action level or the Resuspension Standard threshold. Load-based criteria require more than a simple measure of concentration, since flow must be incorporated into the load estimate. Comparisons to the resuspension criteria must be made on a daily basis for each of the Upper Hudson far-field stations. This will include assessment of the load and concentration seven-day averages and the total load loss for the season vs. the productivity rate.

If dredging occurs in more than one river section, effectively creating two "nearest" far-field stations, this standard applies in the same manner to both stations.

Note that in the event that dredging occurs in more than one river section, effectively creating two "nearest" far-field stations, this standard is applied in the same manner to both stations. That is, the near-field concentration criteria apply to both stations equally. Given the various uncertainties in load estimation, no "pro-rating" of the standard for the upper station will be required, although the dredge operators should consider doing so, as needed. This means that any of the far-field stations can dictate response actions.

The Total PCB load-based criteria will be assessed using the results of the baseline monitoring program, which is scheduled to begin in 2004. Historical data collected prior to the baseline period will be incorporated into the analysis of the baseline data if a relationship between the historical and current baseline data can be developed. Estimates of flow will be derived from USGS gauging stations currently operating in the Upper Hudson, along with data from additional stations developed for this monitoring program (*e.g.*, Schuylerville). As noted previously, the load-based criteria will also be adjusted to reflect the anticipated dredging period length with the maximum allowable net release of 650 kg Total PCBs[18] or 220 kg Tri+ PCB over baseline for the duration of the remediation.

Both of the action levels have associated load-based criteria. To simplify review of the monitoring results and avoid additional computations during the remediation, the load-based criteria will be converted to look-up tables of concentrations that correspond to various load-based levels as a function of river flow and month. Examples of these tables for Total PCBs at the Schuylerville station are included as Tables 4-1 and 4-2 for the Evaluation Level and Control Level far-field net Total PCB load, respectively. The tables were developed using the existing GE data for this location. However, as mentioned previously, the existing water column data from the Upper Hudson are limited in applicability,[19] and were used to provide a preliminary set of values for these tables. Final values for these tables for both Total PCBs and Tri+ PCBs will be developed from the baseline monitoring program. Exceedance of the final values to be developed for these tables from the baseline monitoring program for a given month and given flow will constitute exceedance of the corresponding action level.

Both the Evaluation Level and Control Level contain far-field criteria based on 7-day running averages. These averages are to be calculated daily for comparison against the appropriate criteria on a daily basis. Similarly, both action levels contain near-field suspended solids criteria based on 3-hour, 6-hour or daily running averages. These averages are to be calculated throughout the day on a three hour basis to determine compliance.

For all flux estimates, the load calculation may be corrected for contributions originating upstream of the remediation area (*i.e.*, above Rogers Island) in the event that loads from this region are above the levels typically observed. See Section 4.1.2.7 for the means of adjusting for a significant difference in the upstream loads.

In the event that dredging operations move to a location less than one mile upstream of a far-field monitoring point, the next downstream far-field station becomes the

[18] A daily rate of PCB loading can be derived consistent with the attainment of the recommended Target Cumulative Volume as specified in the Productivity Standard and the cumulative PCB mass delivery to the Lower Hudson. The daily load figure as well as an annual load goal should be prorated according to the production rate planned in the Production Schedule to be submitted annually to USEPA.

[19] Single point monitoring locations at Thompson Island Dam and Schuylerville or any of the far-field stations are not adequate (*i.e.*, not sufficiently representative of river conditions) for the purposes of estimating recent baseline load conditions. A cross-sectional composite sample is required, as will be obtained during both the baseline monitoring and the remedial monitoring programs for this purpose.

representative far-field station for the operation. The nearer far-field station will continue to be monitored, not to judge compliance with the standard, but rather to evaluate the requirement that the far-field station be more than one mile from the remedial operations for the monitoring data to be comparable to the resuspension criteria.

If dredging operations move to less than one mile upstream of a far-field monitoring point, the next downstream far-field station becomes the representative far-field station for the operation.

For exceedance of suspended solids criteria at either near-field or far-field locations, the impacted water column must be sampled at the far-field station to determine the concentration of PCBs in the plume. Suspended solids and turbidity measurements collected from the representative far-field station will document that the sample has been collected from the plume. [20]

In the subsections that follow, the text describes the details of each of the action levels and the threshold. Equations provided in the sections below are the basis for comparing the monitoring results to the resuspension criteria.

4.1.1 Evaluation Level

4.1.1.1 Far-Field Net Total PCB Load

> *The net increase in Total PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 300 g/day for a seven-day running average.*

The far-field net Total PCB load is a load-based criterion (300 grams per day), as opposed to a concentration-based action level (PCB concentration criteria [ng/L]), and is calculated after taking into account the pre-existing baseline loads of Total PCBs. This criterion applies only to the monitoring stations of the Upper Hudson, where a PCB load can be readily estimated. The formula to estimate the dredging-related release using the seven-day running average concentration is as follows:

$$F_7 = \left(\overline{C_{ffs}} - \overline{C_{bl}}\right) \times Q_7 \times T_{d7} \times \frac{0.02832\,m^3}{ft^3} \times \frac{3600s}{hr} \times \frac{1g}{10^9\,ng} \times \frac{1000L}{m^3} \qquad (4\text{-}1)$$

where:

[20] The standard requires that a real-time surrogate be developed and maintained to estimate suspended solids concentrations at the near-field and far-field stations. There may be times when the surrogate fails to predict suspended solids concentrations conservatively and samples will be collected every three hours for suspended solids analysis to measure compliance with the standard.

F_7 = Seven-day average load of Total PCBs at the far-field station due to dredging-related activities in g/day

$\overline{C_{ffs}}$ = Flow-weighted average concentration of Total PCBs at the far-field station as measured during the prior seven-day routine discrete sampling in ng/L.

This is given as:

$$\overline{C_{ffs}} = \frac{\sum_{j=1}^{7} C_{ffs\,j} \times Q_j}{\sum_{j=1}^{7} Q_j} \tag{4-2}$$

where:

C_{ffs} = The Total PCB concentration at the far-field station for day j. If more than one sample is collected in a day due to exceedance of the near-field or far-field criteria, the arithmetic average of all the measurements will be used.

Q_j = The daily average flow at the far-field station for day j,

$\overline{C_{bl}}$ = Estimated 95% upper confidence limit (UCL) of the arithmetic mean baseline concentration of Total PCBs at the far-field station for the month in which the sample was collected, in ng/L. Initial estimates for these values are given in Table 4-3.

This value is determined from baseline monitoring data and represents the upper bound for the average concentration at the far-field station in the absence of dredging. Where the 95% UCL varies within the 7-day period of interest (*e.g.*, at the end of a month), time-weighted average 95% UCL is calculated as the sum of each day's 95% UCL dividing by the number of days.

Q_7 = Seven-day average flow at the far-field station, determined either by direct measurement or estimated from USGS gauging stations, in cfs

T_{d7} = Average period of dredging operations per day for the seven-day period, in hours/day, as follows:

$$T_{d7} = \frac{\sum_{j=1}^{7} T_{d\,j}}{7} \tag{4-3}$$

where: T_{d_j} = The period of dredging operations for day j in hours.

If F_7 is 300 g/day Total PCBs or greater, this is considered to be an exceedance of the Evaluation Level. This formula is intended to identify a mean loading of Total PCBs due to dredging in excess of the action level. The 95% UCL of the water column PCB concentrations at each station and month is chosen to represent baseline concentrations ($\overline{C_{bl}}$), because this is a comparison to the average condition for a short duration. The confidence limit indicates the probability or likelihood that the interval contains the true population value.

Because the seven-day average value will be compared to the monthly mean, it is appropriate to estimate the range of values that may contain the mean. Values that fall outside this range are unlikely to be part of the original population of baseline values; therefore, these PCB export levels are likely to represent a dredging-related release of PCBs. Note that this and all PCB load standards may be adjusted for the production rate as described in subsection 4.1.2.7.

4.1.1.2 Far-Field Net Tri+ PCB Load

The net increase in Tri+ PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 100 g/day day for a seven-day running average.

Equations 4-1, 4-2, and 4-3 will be used to calculate the far-field net Tri+ PCB load at each Upper River mainstem station on a daily basis by substituting the daily Tri+ PCB concentrations and baseline Tri+ PCB 95% UCL values for the Total PCB concentrations. Baseline Tri+ PCB concentrations have not been calculated for this report, but the Tri+ PCB 95% UCLs will be calculated using the data collected during the Baseline Monitoring Program. An F_7 value of 100 g/day Tri+ PCBs or greater constitutes an exceedance of the Evaluation Level.

4.1.1.3 Far-Field Average Net Suspended Solids Concentration

The sustained suspended solids concentration above ambient conditions at a far-field station exceeds 12 mg/L. To exceed this criterion, this condition must exist on average for 6 hours or a period corresponding to the daily dredging period (whichever is shorter). Suspended solids are measured continuously by turbidity (or an alternate surrogate) or every three hours by discrete samples.

The net increase in suspended solids concentration over baseline levels will be calculated during the daily dredging period for each main stem Upper River far-field station. If the suspended solids concentration is estimated continuously using a surrogate, the six-hour running average net increase will be calculated throughout the daily dredging period. If the suspended solids concentration is measured by discrete samples at three-hour intervals, the net increase will be calculated throughout the day for each six-hour interval as the data become available from the laboratory. The suspended solids data must be available within three hours of sample collection (three-hour turnaround time using a modified method for suspended solids analysis). The net increase in suspended solids is calculated as follows:

$$\text{Net Increase in Suspended Solids (mg/L)} = C_{avg} - C_{baseline} \qquad (4\text{-}4)$$

where:

C_{avg} = Arithmetic average suspended solids concentration for the time interval at the far-field station

$C_{baseline}$ = Arithmetic average baseline suspended solids concentration for the same far-field station and month (based on the baseline monitoring program results)

Suspended solids contributions from the tributaries will appear to be dredging-related increases in suspended solids. This criterion may be waived with USEPA review if the increase in suspended solids can be traced to meteorological events. The baseline concentrations at each station will be developed from the results of the baseline monitoring program.

The Evaluation Level is exceeded if the net increase in suspended solids concentration is 12 mg/L or greater at any far-field station.

The Evaluation Level is exceeded if the net increase in suspended solids concentration is 12 mg/L or greater. Exceedance of this criterion prompts Evaluation Level sampling at one far-field station. The station will be chosen to measure the Total PCB concentration in the suspended solids plume in order to determine whether additional actions need to be taken. Sample collection will be timed to measure the concentration of PCBs in the impacted water column. The frequency of this sampling will be equivalent to that defined in Table 1-2 for the representative stations (TI Dam and Schuylerville). Only the grab sample will be collected for this purpose.

4.1.1.4 Near-Field Net Suspended Solids Concentration 300 m Downstream

The sustained suspended solids concentration above ambient conditions at a location 300 m downstream (i.e., near-field monitoring) of the dredging operation or 150 m downstream from any suspended solids control measure (e.g., silt curtain) exceeds 100 mg/L for River Sections 1 and 3 and 60 mg/L for River Section 2. To exceed this criterion, this condition must exist on average for six hours or for the daily dredging period (whichever is shorter). Suspended solids are measured continuously by surrogate or every three hours by discrete samples.

The net increase in suspended solids concentration between the upstream near-field station and the downstream near-field stations will be calculated during the daily dredging period for each remedial operation. Without barriers, these near-field stations will be located approximately 300 m downstream of the dredge. With barriers, these stations will be located approximately 150 m downstream of the barrier. If the suspended solids concentration is estimated continuously using turbidity or any other surrogate, the six-hour running average net increase will be calculated throughout the daily dredging period. If the suspended solids concentration is measured by discrete samples at three-hour intervals, the net increase will be calculated throughout the day for each six-hour interval as the data become available from the laboratory. The suspended solids analysis will require a three-hour turnaround time (using a modified method for suspended solids). The net increase in suspended solids is calculated as follows:

$$Net\ \ Increase\ \ In\ \ SS_{near-field} = C_{avg} - C_{up} \tag{4-5}$$

where:

C_{up} = The arithmetic average upstream near-field station concentration over the time interval

C_{avg} = The arithmetic average downstream concentration over the time interval. Samples will be collected from two stations located 300 m downstream. The average concentration from each location over the time period will be calculated separately and the higher average concentration will be chosen for use in this equation

Evaluation Level exceedances are as follows:

- River Sections 1 and 3: at a net increase in suspended solids concentration of 100 mg/L or higher
- River Section 2: at a net increase in suspended solids concentration 60 mg/L or higher

Exceedance of this criterion prompts Evaluation Level sampling at the nearest representative far-field station. Sample collection will be timed to measure the concentration of PCBs in the impacted water column.

Each near-field 300 m station (150 m station with barriers) will be compared to either 100 mg/L or 60 mg/L, depending on the location of the remediation during Phase 1, while the behavior of the system is tested. In Phase 2, when multiple dredging operations are conducted simultaneously within the same section of the river, the sum of the concentrations measured at the near-field station may be compared to the criteria, because this approach is in keeping with the development of the criteria. This criterion may be waived with USEPA review if the increase in suspended solids can be traced to meteorological events.

4.1.1.5 Near-Field Net Suspended Solids Concentration 100 m Downstream and at the Side Channel Station Without Barriers

> *The sustained suspended solids concentration above ambient conditions at the near-field side channel station or the 100 m downstream station exceeds 700 mg/L. To exceed this criterion, this condition must exist for more than three hours on average measured continuously or a confirmed occurrence of a concentration greater than 700 mg/L when suspended solids are measured every three hours by discrete samples.*

Without barriers, the average suspended solids concentration over the time period at the upstream near-field stations for a remedial operation will be subtracted from the average suspended solids concentration over the same time period at the 100 m downstream station to get the net suspended solids concentration. Also, the average suspended solids concentration over the time period at the upstream near-field stations for a remedial operation will be subtracted from the average suspended solids concentration over the same time period at the side channel station to get the net suspended solids concentration.[21]

> *Exceedance of this criterion prompts Evaluation Level sampling at the nearest representative far-field station.*

If the suspended solids concentration is estimated continuously using turbidity as a surrogate, a three-hour average net suspended concentration of 700 mg/L or higher is an exceedance. If the suspended solids concentration is measured by discrete samples at three-hour intervals, two consecutive samples of 700 mg/L or higher is an exceedance. Exceedance of this criterion prompts Evaluation Level sampling at the nearest representative far-field station. Sample collection will be timed to measure the concentration of PCBs in the impacted water column.

The net suspended solids concentration at each near-field 100 m station or side channel station will be compared to 700 mg/L while the remediation is in Phase 1. In Phase 2, when multiple dredging operations are conducted simultaneously within the same section of the river, the sum of the concentrations measured at the near-field 100 m stations (or side channel station) may be compared to 700 mg/L, because this approach is more in conformance with the development of the criterion. This criterion may be waived with USEPA review if the increase in suspended solids can be traced to meteorological events.

[21] Note that this standard also applies to the 300 m station in the unlikely event that a 700 mg/L event occurs at that location, but does not affect the 100 m and side channel stations.

4.1.2 Control Level

4.1.2.1 Far-Field Total PCB Concentration

> *The Total PCB concentration during dredging-related activities at any downstream far-field monitoring station exceeds 350 ng/L for a seven-day running average.*

The arithmetic average of the past seven days' monitoring will be calculated on a daily basis for each of the Upper River mainstem far-field stations. For each station, a day will be represented by a single value. If more than one sample is collected in a day for a station, the arithmetic average of the Total PCB measurements for a station will be used as a single day's concentration in the seven-day average. If the arithmetic average of the Total PCB concentration is 350 ng/L or higher at a far-field station, this is considered to be an exceedance of the Control Level.

4.1.2.2 Far-Field Net Total PCB Load

> *The net increase in Total PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 600 g/day on average over a seven-day period.*

The far-field net Total PCB load will be calculated using Equations 4-1, 4-2, and 4-3 on a daily basis. A seven-day Total PCB load of 600 g/day or higher constitutes an exceedance of the Control Level.

4.1.2.3 Far-Field Net Tri+ PCB Load

> *The net increase in Tri+ PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 200 g/day on average over a seven-day period.*

Equations 4-1, 4-2 and 4-3 will be used to calculate the far-field net Tri+ PCB load at each Upper River mainstem station on a daily basis by substituting the daily Tri+ PCB concentrations and baseline Tri+ PCB 95% UCL values for the Total PCB concentrations. Baseline Tri+ PCB concentrations have not been calculated for this report, but the Tri+ PCB 95% UCLs will be calculated using the data collected during the baseline monitoring Program. An F_7 value of 200 g/day Tri+ PCBs or greater constitutes an exceedance of the Control Level.

4.1.2.4 Far-Field Average Net Suspended Solids Concentration

The sustained suspended solids concentration above ambient conditions at a far-field station exceeds 24 mg/L. To exceed this criterion, this condition must exist for a period corresponding to the daily dredging period (six hours or longer) or 24 hours if the operation runs continuously (whichever is shorter) on average. Suspended solids are measured continuously by suurogate or every three hours by discrete samples.

The net increase in suspended solids concentration between far-field stations will be calculated on a daily basis for each mainstem Upper River far-field station as soon as the data become available (within 3 hours of sample collection). The net increase in suspended solids concentration will be estimated for the daily dredging period (longer than 6 hours) or for 24 hours if dredging is continuous. Equation 4-4 can be used to calculate the net increase in suspended solids for the time period of concern.

Suspended solids contributions from the tributaries will appear to be dredging-related increases in suspended solids. This criterion may be waived if the increase in suspended solids can be traced to meteorological events.

The Control Level is exceeded if the net increase in suspended solids concentration is 24 mg/L or greater at any far-field station.

The Control Level is exceeded if the net increase in suspended solids concentration is 24 mg/L or greater. Exceedance of this criterion prompts Control Level sampling at one far-field station. The station will be chosen to measure the Total PCB concentration in the suspended solids plume in order to determine if additional actions need to be taken. Sample collection will be timed to measure the concentration of PCBs in the impacted water column. The frequency of this sampling will be equivalent to that defined in Table 1-2 for the representative stations (TI Dam and Schuylerville). Only the grab sample will be collected for this purpose.

4.1.2.5 Near-Field Net Suspended Solids Concentration 300 m Downstream

The sustained suspended solids concentration above ambient conditions at a location 300 meters downstream (i.e., near-field monitoring) of the dredging operation or 150 meters downstream from any suspended solids control measure (e.g., silt curtain) exceeds 100 mg/L for River Sections 1 and 3 and 60 mg/L for River Section 2. To exceed this criterion, this condition must exist for a period corresponding to the daily dredging period (6 hours or longer) or 24 hours if the operation runs continuously (whichever is shorter) on average. Suspended solids are measured continuously by surrogate or every three hours by discrete samples.

The net increase in suspended solids concentration between the upstream near-field station and the downstream near-field stations will be calculated during the daily dredging period for each remedial operation. Without barriers, these near-field stations will be located approximately 300 m downstream of the dredge. With barriers, these stations will be located approximately 150 m downstream of the barrier. The net increase in suspended solids concentration will be estimated for the daily dredging period (longer than 6 hours) or 24 hours if dredging is continuous. Equation 4-5 can be used to calculate the net increase in suspended solids for the time interval of concern.

Control Level exceedances are as follows:

- River Sections 1 and 3: at a net increase of 100 mg/L or higher in suspended solids concentration
- River Section 2: at a net increase of 60 mg/L or higher in suspended solids concentration

Exceedance of this criterion prompts Control Level sampling at the nearest representative far-field station. Sample collection will be timed to measure the concentration of PCBs in the impacted water column.

Each near-field 300 m station (150 m station without barriers) will be compared to either 100 mg/L or 60 mg/L, depending on the location of the remediation during Phase 1 while the behavior of the system is tested. In Phase 2, when multiple dredging operations are conducted simultaneously within the same section of the river, the sum of the concentrations measured at the near-field stations may be compared to the criterion, because this approach is in conformance with the development of the criterion. This criterion may be waived if the increase in suspended solids can be traced to meteorological events.

4.1.2.6 Far-Field Net PCB Seasonal Load

The net increase in PCB mass transport due to dredging-related activities measured at the downstream far-field monitoring stations exceeds 65 kg/year Total PCBs or22 kg/year Tri+ PCBs.

The model projections indicate that no more than 650 kg of dredging-related Total PCBs or 220 kg of dredging-related Tri+ PCBs will be exported during the period of remediation. This is prorated according to the anticipated rate of PCB inventory removal for a season (see subsection 4.1.2.7). During Phase 1, it is anticipated that one-tenth of the PCB inventory will be targeted for removal. Therefore, only one-tenth of this allowable Total PCB load (*i.e.*, 65 kg) or Tri+ PCB load (*i.e.*, 22 kg) will be the maximum allowable release of PCBs during Phase 1, assuming the target production rate is met. Assuming the target productivity schedule is followed, this value rises to 130 kg/yr Total PCBs or 44 kg/yr Tri+ PCBs during Phase 2.

The formula to estimate the dredging-related release to date is:

$$F_{todate} = \left(\overline{C_{ffst}} - \overline{C_{blt}}\right) \times Q_{todate} \times T_{todate} \times \frac{0.02832\,m^3}{ft^3} \times \frac{3600\,s}{hr} \times \frac{1g}{10^9\,ng} \times \frac{1000\,L}{m^3} \tag{4-6}$$

where:

F_{todate} = load loss of Total PCBs at the far-field station for the dredging period to date due to dredging-related activities in g/day

$\overline{C_{ffst}}$ = flow-weighted average concentration of Total PCBs at the far-field station as measured from the start of the dredging period to date in ng/L. For once per day sampling, this is given as:

$$\overline{C_{ffst}} = \frac{\sum_{j=1}^{n} C_{ffst_j} \times Q_j}{\sum_{j=1}^{n} Q_j} \tag{4-7}$$

where:

C_{ffst_j} = Total PCB concentration at the far-field station for day j. If more than one sample is collected in a day, the arithmetic average of all the measurements will be used

Q_j = daily average flow at the far-field station for day j

n = number of days from the start of dredging period

$\overline{C_{blt}}$ = Estimated arithmetic mean baseline concentration of Total PCBs at the far-field station for the period in which the sample was collected, in ng/L. This value is determined from baseline monitoring data. Time-weighted averages are calculated as the sum of the arithmetic average for each day dividing by the number of days

Q_{todate} = average flow at the far-field station, determined either by direct measurement or estimated from USGS gauging stations, in cfs

T_{todate} = average period of dredging operations per day for the time period, in hours/day, as follows:

$$T_{todate} = \frac{\sum_{j=1}^{n} T_{d_j}}{n} \quad (4\text{-}8)$$

where: T_{d_j} = The period of dredging operations for day j in hours.

The allowable F_{todate} in Phase I is 65 kg of Total PCBs if the total PCB mass anticipated to be dredged is 10 percent of the total PCB mass remediated as estimated in the FS (USEPA, 2001). If the production rate is different than 10 percent, the PCB load loss may be adjusted for production rate as described in subsection 4.1.2.7. This formula is intended to identify the amount of loading of Total PCBs due to dredging from the start of the dredging period to the day of measurement. It is based on the collection of grab samples, hence the correction for the daily period of operation. If sampling is conducted on an alternate basis (*i.e.,* composites), this formula will require adjustment to reflect this. The load loss of the Total PCB at the far-field stations will be compared to the allowable load loss for the dredging season.

4.1.2.7 Adjustment to the Load-Based Thresholds

The production rate will be reviewed on a weekly basis. The allowable Total PCB load loss for the season will be adjusted if this target rate is not met using the following equation:

$$AllowableSeasonalTotalPCBLoss(kg) = \frac{m}{M} \cdot 650(kg) \quad (4\text{-}9)$$

where:

m = Total PCB mass anticipated to be dredged in a season (kg)

M = Total PCB mass to be dredged in the remediation (kg), 70,000 kg as estimated in the FS (USEPA, 2001)

The allowable seven-day Total PCB load loss thresholds will be revised if the production rate varies from the anticipated value or the operation schedule differs from that assumed for this report. This revision is to be calculated once per dredging season (*i.e.,* the 7-day running average criterion is set once per season). The equation for estimating the allowable Total PCB load loss is as follows:

$$Load_{TPCB,allowable} = \frac{m_{dredged}}{P_{target} * T} * Load_{threshold} \quad (4\text{-}10)$$

where:

m_{dredge} = Total PCB mass dredged within a period, kg

P_{target} = Targeted production rate, kg/hour. This is given as:

$$P_{target} = \frac{M}{T_d * D_{year} * Y} \qquad (4\text{-}11)$$

where:

M = Total PCB mass targeted to be dredged in the remediation (kg), 70,000 kg as estimated in FS (USEPA, 2001)

T_d = assumed average period of dredging operations per day, 14 hours/day

D_{year} = assumed number of days in one dredging season, 210 days/season

Y = number of dredging seasons during the remediation

$Load_{threshold}$ = Total PCB load thresholds specified in action levels, such as 300 g/day and 600 g/day

The load calculation may be corrected for contributions originating upstream of the remediation (*i.e.*, above Rogers Island) in the event that loads from this region fall above levels typically observed. See subsection 4.1.4.3.

4.1.3 Resuspension Standard Threshold

Resuspension Standard threshold is a confirmed occurrence of 500 ng/L Total PCBs, measured at any main stem far-field station. To exceed the standard threshold, an initial result greater than or equal to 500 ng/L Total PCBs must be confirmed by the average concentration of four samples collected within 48 hours of the first sample. The standard threshold does not apply to far-field station measurements if the station is within one mile of the remediation.

4.1.4 Calculation Details

4.1.4.1 Calculation of Total and Tri+ PCBs from Congener Data

To estimate the Tri+ PCB and Total PCB concentrations from congener data the following equations will be used:

$$\text{Tri+PCBs} = \sum_{i=1}^{n} Congeners_{Tri+,i} \qquad (4\text{-}12)$$

where:

$Congener_{Tri+,i}$ = Concentrations for PCB congeners with three or more chlorine atoms measured

$$\text{Total PCBs} = \sum_{i=1}^{n} Congeners_{all,i} \qquad (4\text{-}13)$$

where:

$Congener_{all,i}$ = Concentrations for PCB congeners measured

4.1.4.2 Non-Detect Values

Half the detection limit will be substituted for nondetect values in the formulas.

4.1.4.3 Upstream Source Concentrations

To identify the load contributions originating upstream of the remediation area (i.e., above Rogers Island), the 7-day running average of the Total PCBs should be used and compared to the monthly baseline average obtained from the baseline monitoring program. Appropriate means test should be used when comparing the 7-day running average to the baseline monthly average. Prior to performing the means test, the following should be considered:

- Normality – test for normality of the data, either using W-Test for n<=50 or Kolmogorov-Smirnov Test for n>50.
- Data transformation – repeat the test for normality on transformed data for parameters that are no normally distributed.
- Homogeneity of variance – test for homogeneity of variance using Levene's test.

After considering the above criteria, perform the appropriate one-tailed means test comparison:

- For normally distributed data, t-test should be used if the variance is homogeneous, otherwise approximate t-test should be used.
- For data that are not normally distributed, the non-parametric Mann-Whitney U test should be used.

After the means test is performed, the downstream load calculations may be corrected by subtracting the load obtained from the difference between the average concentrations. The additional load originating from upstream source can be calculated as follows:

$$F_{RI} = \left(\overline{C_{RI}} - \overline{C_{RIbl}}\right) \times Q_{ff} \times T_{d7} \times \frac{0.02832\,m^3}{ft^3} \times \frac{3600s}{hr} \times \frac{1g}{10^9\,ng} \times \frac{1000L}{m^3} \qquad (4\text{-}14)$$

where: F_{RI} = Average additional load of Total PCBs originating from upstream source in g/day,

$\overline{C_{RI}}$ = Seven-day average concentration of Total PCBs from upstream source (above Rogers Island) in ng/L.

$\overline{C_{RIbl}}$ = Baseline monthly average concentration of Total PCBs from Baseline Monitoring Program.

Q_{ff} = Average flow at the far-field station, determined either by direct measurement or estimated from USGS gauging stations, in cfs, and

T_{d7} = Average period of dredging operations per day for the seven-day period, in hours/day, as defined in equation 3.3.

The corrected downstream load is then:

$$F_{7corr} = F_7 - F_{RI} \qquad (4\text{-}15)$$

where: F_{7corr} = Corrected load at the far-field station in g/day.

F_7 = Seven-day average load of Total PCBs at the far-field station due to dredging-related activities in g/day.

F_{RI} = Average additional load of Total PCBs originating from upstream source in g/day.

4.2 Monitoring Plan for Compliance with the Standard

Implementation of the monitoring program for compliance is provided in the subsections 4.2 and 4.3. Measurement techniques, monitoring locations, parameters, sampling frequency and requirements of the standard are provided. Attachment F provides a description of measurement techniques for the continuous monitoring requirements. Some of the more stringent aspects of this monitoring program, such as the need to have a real-time surrogate measurement of suspended solids to provide a warning of elevated contaminant levels, may be relaxed after Phase 1. A clear rationale for each element of the monitoring plan is presented in Section 3. Additional monitoring in the form of special studies is required to gather information that can be used to refine the standard. This is described in subsection 4.4.

4.2.1 Measurement Technologies

Sampling techniques and technologies have been reviewed to select the appropriate means of obtaining the monitoring data needed to confirm adherence to the standard. The far-field monitoring will be similar to the baseline monitoring program implemented during the remedial design period (2003 – 2005). The near-field monitoring will have a reduced set of parameters and has little relation to previous sampling efforts. Some additional components will be required to give a full picture of the conditions during dredging *(e.g.*, continuous monitoring for PCBs), but will not be assessed against the action levels in Phase 1.

Instruments that provide an instantaneous measure of water column conditions will be used for the following parameters:

- Turbidity
- Dissolved oxygen
- Temperature
- pH
- Conductivity
- Laser particle counters

Continuous measurement of water column conditions will be made for:

- Turbidity
- Laser particle counters
- Integrating sampler for PCBs (continuous sampler)

The analytical methods will need to be sensitive enough to measure water column concentrations at each station. This is most important for PCBs. For Total and Tri+ PCBs, a congener-specific method with a detection limit low enough to detect expected PCB congener concentrations at Bakers Falls, Rogers Island, and Waterford is required.

4.2.2 Consistency with the Baseline Monitoring Program

There will be several monitoring programs developed throughout the remediation. The primary programs are:

- Baseline
- Remedial
- Long-term

Measurement techniques and stations or substation locations must be carefully selected.

To capture a consistent picture of the site conditions, there must be consistency throughout the programs on key issues. Two items that must be carefully chosen are the measurement techniques (analytical or direct reading) and the locations of the stations or substations.

The analytical methods chosen for this program must meet or exceed the specifications of the methods used in the baseline monitoring program in terms of precision, sensitivity, accuracy, representativeness, comparability, completeness and sensitivity. The only exception to this requirement will be the modified method specified for TSS to allow a reduced turn-around time. The same analytical methods chosen for each station will be maintained at each station throughout the program for consistency.

Data collected during baseline monitoring will be the means of differentiating dredging-related loads from baseline loads.

The same stations must be occupied during the remediation as during the baseline monitoring program. Any change to the location or method of collection will result in changes to the resulting data that cannot be easily accounted for, confounding estimates of PCB conditions. The data collected during baseline monitoring will be the means of differentiating dredging-related loads from baseline loads. A correction would need to be applied to the baseline data to properly determine compliance with the load-based resuspension criteria, but there is no basis for developing this correction factor. Therefore, it is essential to maintain the same monitoring locations and sampling methods.

Two important aspects of the baseline monitoring program are the equal discharge interval sampling method and the requirement that samples collected from the water column cannot be split among multiple sample jars. These requirements must be maintained for the resuspension standard monitoring program.

4.2.3 Compliance Monitoring Programs

Monitoring will be required for at least the remedial operations listed below. Other operations related to dredging may be included as well:

- Dredging
- Debris removal
- Resuspension control equipment removal
- Off loading to the processing facility
- Cap placement
- Backfill placement
- Installation of containment devices other than silt curtains (sheet piling and other structural devices requiring heavy equipment operation and disturbance of the river bottom)
- Shoreline excavation and restoration

The following remedial operation will not require near-field monitoring:

- Silt curtain placement

4.2.3.1 Far-Field Monitoring

The far-field stations will be used to monitor water column conditions in the Upper and Lower Hudson River. These results are needed for comparison to the baseline water column concentrations to estimate the magnitude of any dredging-related release. Due to the anticipated extent of remediation and associated barge traffic, dredging-related releases may not be limited to a single area; thus, monitoring of multiple stations is anticipated throughout the dredging period.

A surrogate real-time measure of suspended solids will be used as an indicator of dredging-related releases, assuming the mechanism for increased PCB concentrations associated with dredging will be resuspension of contaminated sediment.

The parameters of primary interest are PCBs and related parameters including turbidity, suspended solids, DOC, and suspended OC. A surrogate real-time measure of suspended solids will be used as an indicator of dredging-related releases, assuming the mechanism for increased PCB concentrations from dredging operations will involve the resuspension of contaminated sediment. DOC and suspended OC describe the dissolved and suspended matter distribution of PCBs in the water column. These parameters also may be useful in determining the source of elevated concentrations.

Discrete Samples

The far-field Upper Hudson River sampling will require the measurement of PCB congeners, suspended solids, and OC by taking discrete, cross-sectional grab samples. These measurements are necessary to assess the impacts of the dredging operations and to provide a basis for a warning system for the downstream water intakes. The required sampling in the Lower Hudson River is similar to the far-field Upper Hudson River sampling, but is more limited in the extent and frequency of sampling. Data from these samples will identify increased impacts to the Lower Hudson River from dredging and be compared to resuspension criteria.

Unless stated otherwise, the monitoring and sampling at each station will be performed using equal discharge increment (EDI) sampling for the Phase 1 monitoring program. Equal width increment (EWI) sampling techniques may be considered for an alternate Phase 2 monitoring program. The EDI or EWI methods usually result in a composite sample that represents the discharge-weighted concentrations of the stream cross-section for the parameter that is being monitored or sampled. The EDI and EWI methods are used to divide a selected cross section of a stream into increments having a specified volume of flow or width.

The samples will be integrated both vertically and horizontally. The term vertical refers to that location within the increment at which the sampler or the measurement probe is lowered and raised through the water column. EWI verticals are located at the midpoint of each width increment. EDI verticals are located at the centroid, which is a point within each increment at which stream discharge is equal on either side of the vertical. If properly implemented, EDI and EWI methods should yield identical results. These sampling methods will be applied for all parameters measured in the water column.

Daily average flow rates at each far-field station will be recorded for comparison of the discrete sample measurements to the load-based criteria.

Continuous Integrating Samplers for PCBs

Continuous integrating samplers will be set up at the far-field stations between Fort Edward and Waterford. These samplers will be used throughout the dredging program to integrate PCB loads and concentrations over time, providing a measure of PCBs releases between the discrete samples. Integrating data over time intervals in the periods between the discrete water column samples will enable identification of dredging-related releases, including dissolved-phase PCBs that cannot otherwise be identified by examining surrogate measurements such as suspended solids. The Phase 1 results may be used to develop resuspension criteria for Phase 2.

Continuous Monitoring for Suspended Solids Surrogate at the Representative Far-Field Stations

The suspended solids will be continuously monitored via surrogate direct reading monitors (*e.g.*, laser diffraction-based particle counters and turbidity monitors). A special study will be conducted to determine an initial surrogate relationship (see subsection 4.4) that will allow the suspended solids concentrations to be estimated in real time, which provides a warning system for downstream water intakes in the Hudson River. The real-time estimates of suspended solids will be compared to measured values from samples collected once per day at each station. At least three substations must be monitored (one in the channel, one on each shoal), but preferably, five or six substations will be occupied in the same manner as the Baseline Monitoring Program sampling.

If the relationship between surrogate and TSS does not provide sufficiently accurate estimates of TSS, samples will be collected for suspended solids analysis every three hours with a three-hour turn-around (using a modified TSS method) for compliance to the standard until an appropriate surrogate relationship is developed and implemented. In the event of an exceedance of the suspended solids resuspension criteria based on the surrogate measurement, TSS samples will be collected for confirmation twice a day at the station with the exceedance.

All continuous monitors will be checked daily for problems such as bio-fouling and damage.

Suspended Solids Collection at Other Downstream Far-Field Stations

The standard requires that samples be collected for suspended solids analysis every 3 hours on a 24-hour basis at the downstream far-field stations, excluding the representative far-field station. These samples will be collected by means of automatic samplers placed in the cross-section of the river. At a minimum, there will be one center channel station and two shoal stations, one on each side of the river, but preferably these samplers will be deployed in a manner that is consistent with EDI. The samplers must be capable of collecting and storing a series of three hour composite samples. The samples will be collected twice a day. The turnaround time for these results will be 12-hours. Decontamination procedures must be developed for these samplers that meet with USEPA approval.

Monitoring Parameters Without Resuspension Criteria

Monitoring parameters required by the performance standard (*i.e.*, discrete measures taken whenever samples are collected for PCB or suspended solids analysis), but not compared to resuspension criteria, are:

- Temperature – because the distribution of PCB concentrations between the dissolved and suspended phases is partially dependent on water column temperature.
- pH – to provide a measure of quality assurance by comparing values to the New York State surface water standard (6.5 to 8.5 [6 NYCRR part 703.3])
- Conductivity – to provide a measure of quality assurance
- DO - because high suspended solids could exert a demand on oxygen levels, which is potentially damaging to biota in the region of the dredge.

4.2.3.2 Near-Field Monitoring

Monitoring in the near field will be performed to determine the suspended solids releases. This will include both continuous measurements of surrogates and discrete samples.

Continuous monitoring for a suspended solids surrogate is required to address two goals of the Phase 1 standard:

- To provide a real-time measure of conditions surrounding the dredging operation
- To provide feedback to the dredge operator

The real-time measure provides an immediate signal to the dredge operator in the event of an unexpected release. It also provides the dredge operator with feedback in the form of information on the amount of resuspension resulting from various dredge manipulations. Using this information, the dredge operator is expected to optimize the manipulations of the dredge to avoid unnecessary resuspension. Based on this need, continuous reading probes must be deployed in the near field even if their output does not yield a sufficiently useful estimate of TSS.

The continuous suspended solids monitoring consists of monitoring suspended solids via surrogate direct reading monitors (*e.g.*, turbidity monitors) at each near-field station. A special study will be conducted to determine an initial surrogate relationship (see subsection 4.4). This relationship will allow the suspended solids concentrations to be estimated in real time based on the continuous reading probes. The real-time estimates of suspended solids will be compared to measured values from samples collected once per day at each station.

If the relationship between surrogate and suspended solids is not sufficiently protective of the various action level criteria, samples will be collected for suspended solids analysis every three hours with a three-hour turnaround (using a modified TSS method) for compliance to the standard until an appropriate surrogate relationship is developed and implemented. In the event of an exceedance of the suspended solids resuspension criteria based on surrogate readings, samples will be collected for confirmation twice a day at the station with the exceedance.

Continuous monitors will be deployed such that the measurements are made from the middle of the water column (halfway between the river bottom and the water surface).

Continuous monitors will be checked daily for problems such as bio-fouling and damage.

Daily particle counter measurements will be required at each near-field monitoring location. This will provide an additional means of relating a real-time measurement to suspended solids.

4.2.4 Monitoring Locations

The monitoring plan has two baseline stations (Bakers Falls and Rogers Island), four Upper Hudson far-field stations, and two Lower Hudson far-field stations. In addition, each dredging operation has 5 near-field stations.

4.2.4.1 Far-field Monitoring

The following stations, locations of which are shown in Figure 1-2, comprise the far-field monitoring stations for the Upper Hudson River:

- TI Dam[22]
- Schuylerville
- Stillwater
- Waterford

Two upstream baseline stations will be monitored in the Upper Hudson River:

- Bakers Falls
- Rogers Island

The Bakers Falls and Rogers Island stations represent baseline conditions for the remediation area and thus need to be monitored regularly to avoid confusion between

[22] The Thompson Island Dam station will be a true cross-sectional station, as opposed to the historical TID West or PRW2 stations.

dredging-related releases and those that may have occurred upstream. The frequency of monitoring at Bakers Falls will be less than that at Rogers Island, if the Bakers Falls station continues to exhibit low baseline levels of PCBs and suspended solids relative to Rogers Island conditions.

In the Lower Hudson River, the following stations will be monitored:

- Albany
- Poughkeepsie

In addition to these Lower Hudson River stations, a monitoring station will also be required on the Mohawk River at Cohoes to estimate PCB loads from the Mohawk watershed. This station will be used in conjunction with the measurements at the Lower Hudson River monitoring locations to aid in identifying the fraction of any PCB load increase from the Mohawk River, as opposed to the Upper Hudson River remedial activities.

The daily (and any continuous) measurements at the far-field stations must reflect the river cross section at the monitoring location by using EDI (USGS, 2002). At least five locations will be monitored in each cross section. Discrete samples in the cross section may be composited, but continuous reading devices (*i.e.*, turbidity) are required at multiple locations in the cross section.

4.2.4.2 Near-Field Monitoring Locations

Near-field monitoring locations are associated with individual remedial operations and move as the operation moves. The data from these locations have two principal objectives: provide feedback to the dredge operator and, provide a measure of suspended solids release from the operation. Each remedial operation requires five monitoring locations, which are arranged as shown in Figure 1-1 and described as follows:

- One station located approximately 100 m upstream of the dredging operation will monitor water quality conditions entering the dredging area to establish ambient background conditions.

- One station located 10 m to the channel side of the dredging operation will monitor local boat traffic impacts.

- One station located 100 m downstream of the dredging operation or 50 m downstream of the most exterior silt control barrier will monitor the dredge plume.

- Two stations located 300 m downstream of the dredging operation or 150 m downstream of the most exterior silt control barrier will monitor the dredge plume.

The locations and associated criteria were chosen using the TSS-Chem model assuming that a single dredging operation was achieving full production (refer to Attachment D of this report). If control barriers are installed, the five stations will be placed outside of the barrier. A sixth location within the barrier is required in the controlled area downstream of the dredge. While there is no standard for this inner station, it is needed to develop a relationship between conditions inside the silt barriers and the near-field monitoring stations downstream. The distances from the remedial operations are approximate and the location of the near-field stations may be changed in the field to better capture the plume, if USEPA approves the change.

Work plans developed for the remediation must specify a means of verifying that the downstream monitors are placed to capture the plume.

It is acknowledged that the location of remedial operations and control barriers will be determined during the design. As a result, the location of the near-field monitoring stations can only be anticipated in this standard, but will be reviewed as a part of the design. Work plans developed for the remediation must specify a means of verifying that the downstream monitors are placed to capture the plume. The acoustic doppler current profiler (ADCP) may be useful in this regard. With changing river conditions and movement of the dredge, periodic adjustment of the monitoring locations will be required.

4.2.5 Potential for Reduction in the Near-Field Monitoring Locations

In order to provide an accurate representation of the suspended solids around the dredging operations, all five monitoring (or six with containment barriers) are necessary. However, if remedial operations are located in close proximity to one another, it may not be feasible to maintain all of the locations since they may pose a safety concern to the technicians or they will be within the working area for a downstream operation. In this case, monitoring locations may be dropped at the discretion of the construction manager for as long as this condition exists.

Such decisions must be documented in the weekly reports. At this time, it is anticipated that stations will be dropped only if the remedial operations are located on the same side of the river. A more prescriptive definition of the conditions when dropping a station would be appropriate cannot be developed at this time, because this is contingent on design specifications, including equipment types and schedule, that are not presently available.

A possible example of conditions in which the number of stations can be reduced is when remedial operations are conducted within 600 m (0.25 mile) of each other on the same side of the river. This is the distance initially prescribed between the upstream station and the farthest downstream stations, assuming no containment. In this situation, the monitoring locations of the upstream operation would fall within the work zone of the downstream operation. To remedy this, one or more of the downstream monitoring locations for the upstream operation may be dropped. Additionally, the remaining stations may serve as both downstream monitors for the upstream operation as well as baseline monitors for the downstream operation.

If the operations are sufficiently close (*i.e.*, within 0.25 miles and on the same side of the river), the USEPA field coordinator may approve the monitoring of the two operations as a single unit, thus halving the monitoring requirements. A similar configuration may occur for contained areas, but the revisions to the monitoring program cannot be specified, without further information to be developed during the design.

4.2.6 Frequency and Parameters

Tables 1-2, 1-3, and 1-4 contain the parameters and frequency of sampling required by the Resuspension Standard for routine monitoring and each action level. The parameters required are constant throughout, but the sampling method or analytical technique may differ in some instances. The sampling frequency varies by station and action level.

4.2.6.1 Analytical Methods for Suspended Solids

Suspended solids measurements are required at both near-field and far-field stations. While a surrogate measurement of suspended solids concentrations is in use for compliance with the standard, a method equivalent to ASTM method 3977-97 will be used with a turnaround time of 12 hours. This method will be equivalent to the suspended solids analysis specified for the baseline monitoring program. A second modified method will be specified that will allow an estimate of suspended solids concentrations to be made with a three-hour turnaround time. Modifications to the standard method to permit a reduced turnaround time may include:

- Collection of a larger sample volume when suspended solids are visibly low
- Reduction in drying time
- Higher drying temperature
- Field filtration

Co-located samples for both the standard and modified suspended solids methods will be collected at a frequency of once per day for the first month of operation. The samples should be collected from a range of concentrations to permit a full comparison of the methods. If the methods are in good agreement (relative percent difference is less than 30%), the sampling frequency for co-located samples by the full ASTM method may be reduced.

4.2.6.2 Sampling Methods for Suspended Solids

Suspended soilids samples will be collected for confirmation of the surrogate measurements and compliance monitoring (in place of the surrogate measurements), and in support of the PCB analyses. The collection method for confirmation of the surrogate measurements will differ in that the sample must collected at the location of the turbidity sensor. For the far-field stations, the volume that is equivalent to the percentage of discharge that a continuous monitor represents must be acquired for each substation. The collection method for compliance monitoring will be vertically integrated samples at each near-field station or compliance with the EDI method at the far-field station. The sampling for supporting information for PCB analyses will be consistent with the PCB sample collection process.

No splitting of water samples is permissible for any measurements that must accurately reflect the suspended solids content. If duplicate samples are required, the sample bottles for the duplicate and sample analysis can be deployed at once or in series to generate co-located samples. Sample bottles for PCB and suspended solids analysis should be deployed simultaneously if possible.

No splitting of water samples is permissible for any measurements that must accurately reflect the suspended solids content.

4.2.6.3 Far-field Monitoring Parameters and Frequency

Table 4-4 presents the relevant information for each parameter that will be monitored as part of the far-field Upper Hudson River program. PCB congeners will be analyzed using the Green Bay method or an equivalent method. Attachment F-2 provides a synopsis of PCB analytical methods and associated detection limits. As stated above, the analysis for suspended solids will be conducted using a method equivalent to ASTM method 3977-97. The entire sample collected will be used for the suspended solids and PCB analyses.

All measurement techniques require sufficient sensitivity to avoid non-detect values at most stations. For PCB congeners, low detection limits will be required at Bakers Falls, Rogers Islands, and Waterford. Discrete samples must be collected from a potentially impacted water parcel as it passes the station, although samples from different stations do not need to be timed to correspond to the same water parcel.

The type of integrating sampler will be determined during design. Analysis for DOC, suspended OC, and suspended solids will be required in addition to PCB congeners for these samples, if this is appropriate for the type of sampler chosen.

The standard requires that samples for suspended solids be collected every three hours continuously at each of the far-field stations, but that at the near representative far-field station, a surrogate relationship will be developed to have a real-time indication of the suspended solids concentrations. If suspended solids analyses for compliance have a turn-around time of 12 hours at all other far-field stations, but if samples are collected for compliance at the representative near-field station (*e.g.*, TI Dam if dredging is limited to the TI Pool), the turn-around time is three hours. It will be permissible to use an integrated sampler to collect the eight samples per day for suspended solids (if the sampler is capable of collecting eight separate samples over time) and sending all eight samples to the laboratory once per day. This will greatly reduce the labor requirements for the monitoring program.

Whole water samples for PCB analysis must include a process to extract PCBs from the dissolved and suspended phases separately, using matrix-specific extraction and cleanup methods used for the Reassessment RI/FS or similar methods demonstrated to be capable of achieving equivalent extraction efficiencies. Justification for this approach is provided in Attachment F-3. Analyses may be done on the combined extracts.

Routine and non-routine monitoring of the 6 Upper River mainstem stations will both require the same analysis, but sampling method and frequency will vary with the station and action level.

Routine monitoring of the six Upper River mainstem stations will consist of grab samples and continuous monitoring. Non-routine monitoring will require the same analyses, but the sampling method and frequency will vary with the station and action level. Grab samples will be composited from five or six samples in the cross section using the EDI sample collection method and consistent with the approach taken during the baseline monitoring program. Continuous monitors will be located in at least three locations (on channel station and two shoal stations), although it would be preferable to have the stations deployed consistent with EDI or EWI locations.

At Bakers Falls, one whole water PCB sample will be collected per week. DOC, suspended OC, and suspended solids will be measured for these samples. The surface water quality parameters to be measured are as follows:

- Turbidity
- Temperature
- pH
- Conductivity
- DO

Routine and non-routine monitoring are the same for this station. Laboratory results must be available within 72 hours of the collection of the sample. This station will be sampled from only one location in the cross section.

At Rogers Island, one whole water PCB sample will be collected per day. DOC, suspended OC, and suspended solids will be measured for these samples. Surface water quality parameters to be measured continuously are as follows:

- Turbidity
- Temperature
- pH
- Conductivity

Dissolved oxygen measurements will be made along with each grab sample collected for suspended solids. Samples will be collected for suspended solids every 3 hours, 24 hours per day. An integrating sampler will be deployed continuously for a two-week period throughout the construction season. The turn-around time for the PCB analysis is 72 hours from the collection of the sample. Routine and non-routine monitoring are the same for this station. The monitoring frequency at Rogers Island may be reduced to weekly for all parameters except suspended solids, if the data will not be used to monitor for releases from the upstream sources that could be interpreted as releases from the remediation. Reduction in frequency at this station will require approval from USEPA.

USEPA has not yet identified the location of the Phase 1 dredging. Assuming that the remediation will be limited to the northern end of the TI Dam during Phase 1, there will be two representative stations that are sampled with a shorter turn-around and a higher frequency for monitoring contingencies: the TI Dam and Schuylerville stations.

During Phase 1, the Stillwater and Waterford stations will be monitored to measure the PCB concentrations entering the Upper Hudson River public water treatment plants in Halfmoon and Waterford, and to confirm or adjust the means of by which Total PCB concentrations for the Waterford station have been estimated based on the concentrations at the upstream stations. This information will be important during Phase 1 to understand the behavior of the system, but the frequency of sampling at these downstream locations will most likely be reduced in Phase 2.

Routine monitoring for the four Upper River far-field stations from the TI Dam to Waterford will be identical to the monitoring at Rogers Island, with some exceptions:

- Suspended solids will be continuously monitored with a particle counter at these stations.
- Grab sample laboratory results for parameters other than suspended solids must be available within 24 hours of the collection of the sample for the TI Dam and Schuylerville.
- The nearest representative station, which would be the TI Dam station if dredging is conducted in the TI Pool throughout Phase 1, will be required to have a surrogate relationship for suspended solids concentrations in place of the suspended solids sampling.

Non-routine monitoring at the two representative stations (TI Dam and Schuylerville) will increase in frequency for the PCB, DOC, suspended OC, and suspended solids samples, and the PCB analyses will be on the dissolved and suspended phases instead of whole water. For the Evaluation Level, the samples will be collected twice a day. For the Control Level samples will be collected three times a day. For the Resuspension Standard threshold, the samples will be collected four times a day, but will be composited from samples collected hourly over one six-hour period.

The deployment period for the integrating sampler will also vary. For the Evaluation Level, the deployment period is the same as for routine monitoring. For the Control Level, the integrating sampler will be deployed for periods of one week. For the Resuspension Standard threshold, the integrating sampler will be deployed for one-day periods.

The sampling frequency and turn-around time is unchanged from routine monitoring for the Evaluation Level for Stillwater and Waterford, the farthest downstream stations. The sampling method changes for the Control Level from discrete grab samples to daily integrating samples to capture the average concentration in what could be a rapidly changing environment.

Sampling frequency and turn-around time for Stillwater and Waterford is the same as routine monitoring for the Evaluation Level but changes from discrete grab samples to daily integrating samples for the Control Level.

The analytical results will be required within 24 hours for the Control Level. This shorter turn-around time requirement is warranted for this action level because the Total PCB concentration could be approaching the Resuspension Standard threshold, or because the PCB load loss to the Lower Hudson River has exceeded the allowable rate for an extended period of time. For the Resuspension Standard threshold, these stations will be sampled four times a day for:

- Whole water PCBs
- DOC
- Suspended OC
- Suspended solids
- Surface water quality

In addition, an integrating sampler will be deployed for one-day periods. The turn-around time for PCB analyses from the integrating sampler will only be specified where the information is needed quickly for comparison to the resuspension criteria. For the Resuspension Standard, the turn-round times will be 24 hours for the two representative far-field stations (TI Dam and Schuylerville stations) and the stations farther downstream (Stillwater and Waterford stations). For the Concern and Control Levels at Stillwater and Waterford, the turn-around times will be 72 hours and 24 hours, respectively.

These monitoring contingencies are for remediation of River Section 1 more than one mile upstream from the TI Dam monitoring location. If dredging were conducted in River Sections 2 and 3, the two stations downstream of the dredging will have the parameters, frequency, sampling methods, and turn-around times associated with the TI Dam and Schuylerville as described above, and stations below these stations will have the parameters, frequency, sampling methods and turn-around times associated with Stillwater and Waterford, also as described above.

If the remediation is conducted in more than one river section, more than two stations are representative. If there were an accidental release in a section that was not undergoing remediation at that time, the two stations at least one mile downstream of the accidental release would be representative until the situation was resolved. Representative stations must always be more than one mile downstream from the source of the resuspended material. In the event that a far-field suspended solids resuspension criterion is exceeded, the far-field station would be monitored for PCBs.

In the event that a far-field suspended solids resuspension criterion is exceeded, the far-field station would be monitored for PCBs.

Exceedance of Evaluation Level criteria will prompt far-field Evaluation Level discrete sample monitoring requirements. Exceedance of Control Level criteria will prompt far-field Control Level monitoring discrete sample monitoring requirements. This additional far-field sampling will be limited to the nearest downstream representative far-field station or the next downstream station, depending on the location of the plume causing the exceedance. Sample collection will be timed to capture the plume. The frequency, parameters and sampling methods will be the same as those defined for the TI Dam and Schuylerville in Table 1-2.

If the monitoring requirements change because of exceedance of a resuspension criterion or reverting to lower action levels, the deployment period of the continuous integrating samplers may change before completion of the period. If the deployment period is reduced, the sample already collected will be sent for analysis. If the deployment period is extended, the sampling period can be extended to match the new requirements.

Affirmation Sampling

Integrating PCB samplers are required to verify whether the grab samples are sufficiently indicative of average river conditions. The deployment for the integrating sampler varies from routine monitoring to different action levels. For routine monitoring and evaluation level, the deployment periods are once every two weeks. At the control level, the integrating sampler deployment periods at TID and Schuylerville are increased to once a week. For Stillwater and Waterford far-field stations, the deployment periods are increased to once a day at the control level. Similarly, at the resuspension standard threshold, the deployment periods are once a day for all the far-field stations.

To ensure that the grab samples represent the average river conditions, the appropriate means test comparison of the grab samples to the integrated samples need to be performed. To perform the means test comparison, the following should be considered:

- Normality – test for normality of the data, either using the W-Test for n<=50 or the D'Agostino Test for n>50.
- Data transformation – repeat the test for normality on transformed data for parameters that are not normally distributed.

After considering the above criteria, perform the appropriate one-tailed means test comparison:

- For normally distributed data, t-test should be used if the variance is homogeneous, otherwise approximate t-test should be used.
- For not normally distributed data, the non-parametric Mann-Whitney U test should be used.

If the means test results indicate that the mean of the grab samples is not statistically different from the corresponding integrating samples, the sampling frequencies and approach for both the grab and integrating samplers are appropriate. On the other hand, if the means test indicate that the mean of the grab samples is statistically different from the mean of the integrating samples, additional study for both integrating and grab samples needs to be performed to assess the adequacy of the grab and integrating samples.

4.2.6.4 Lower Hudson River and the Mohawk River at Cohoes

Far-field stations in the Lower Hudson River and at one location in the Mohawk River will require routine monitoring. Sampling at these stations will include the analysis of PCBs congeners, DOC, suspended OC, and suspended solids. The samples will be whole water, not split phase. Discrete measurements will be made for the following:

- Surface water quality measurements for turbidity
- Temperature
- pH
- Conductivity
- DO

The results of the analyses will be required within 72 hours. Samples will be collected every four weeks under routine monitoring. (This low frequency is contingent on the results of the baseline monitoring program showing Total PCB concentrations less than 100 ng/L on average to allow a margin of safety for the public water supplies.) The Mohawk River station will be sampled using EDI, but only a single center-channel station is required for the Lower Hudson River stations.

Non-routine monitoring at these locations will be triggered by an estimated Total PCB concentration of 350 ng/L or higher at Waterford or Troy. The first round of non-routine monitoring will be timed to capture the parcel of water that triggered the non-routine Lower Hudson River and Mohawk River monitoring.

The concentration is estimated using the following equation:

$$C_{Lower\ \ Hudson} = C_{Far-field} \times \frac{Q_{Far-field}}{Q_{Troy}} \qquad (4\text{-}16)$$

where:

C_{Troy} = Estimated water column concentration Troy

$C_{Far\text{-}field}$ = Measured water column concentration at the far-field station

$Q_{Far\text{-}field}$ = Instantaneous flow at the far-field station (cfs) at the time of sample collection

Q_{Troy} = Instantaneous flow over Federal Dam at Troy

4.2.6.5 Near-field Monitoring

Routine Sampling for Compliance

The parameters that are monitored in the near field are summarized in Table 4-5 along with the relevant information for each parameter. The standard requires that a surrogate real time measurement for suspended solids be developed and maintained throughout the program for compliance with the near-field resuspension criteria. It is expected that turbidity will be the surrogate measure chosen.

Each near-field station will have continuous monitoring for turbidity, temperature, and conductivity for one hour prior to beginning remedial operations and for at least two hours after the operation ceases. This applies to the five stations required if there are no barriers installed, and to all six stations if barriers are installed. The information from these monitors will provide immediate feedback to the dredge operator.

Confirmation Sampling of the Surrogate

Samples will be collected daily from each near-field monitoring location for confirmation of the surrogate relationship. The ability of the surrogate to adequately predict the suspended solids concentrations will be assessed on a daily basis. The criteria and method for assessing the surrogate relationship is provided in Section 4.4. If the resuspension criteria are exceeded at a near-field monitoring station, two samples will be collected per day for confirmation of the surrogate.

In the event that the surrogate fails to adequately predict the suspended solids concentrations, samples will be collected every three hours and analyzed for suspended solids using the modified method with a three-hour turn-around. Vertically integrated samples will be collected from each near-field station every three hours with the results of the analysis available within three hours. These results will be compared to the resuspension criteria. One sample from each near-field station will be collected one-hour prior to beginning the remedial operations at a location.

After completing the remedial operation, at least two samples collected one hour apart will be used to confirm that the suspended solids concentrations have stabilized. This will require the sampling to continue for at least another four to five hours because of the three-hour turn-around time on the analyses. More samples will be required if the suspended solids concentrations have not stabilized two hours after completing the remedial operation. If the remediation is halted due to hazardous conditions such as thunderstorm, the near-field monitoring to show that the suspended solids concentrations have stabilized will not be required.

After completing the remedial operation, at least two samples collected one hour apart for four to five hours will be used to confirm that the suspended solids concentrations have stabilized.

Other Parameters

Discrete laser particle counter measurements will be made on any samples collected for suspended solids analysis.

At both the near-field and far-field stations, pH and DO will be monitored discretely each time a sample is collected.

Exceedance of the Near-Field Resuspension Criteria

Exceedance of near-field Evaluation Level suspended solids criteria will prompt far-field Evaluation Level monitoring. Similarly, exceedance of near-field Control Level suspended solids criteria will prompt far-field Control Level monitoring. This additional sampling will be limited to the nearest downstream representative far-field station and timed to capture the plume from the remedial operation. The frequency, parameters and sampling methods will be the same as those defined for the TI Dam and Schuylerville, as shown in Table 1-2.

Engineering Evaluations

Additional sampling in the near field may be conducted as a part of the engineering evaluations. Samples for PCB analysis may be collected in the vicinity of the dredges or in other areas affected by the remediation. The same sampling and analytical methods will be used for comparison to the near-field and far-field data.

4.3 Reverting to Lower Action Levels

Any reduction in monitoring requires approval from USEPA before the changes are made. USEPA may approve a reduction in the level of monitoring when the following occurs for Total PCB criteria:

- For the exceedance of a Control Level concentration criterion, the running average concentration must fall below the action level for one week before the contingencies can be relaxed.

- For the exceedance of a Evaluation or Control Level seven-day running average load-based criterion, the running average load level must fall below the action level for one week before the contingencies can be relaxed.

- Following exceedance of Resuspension Standard threshold, temporary halting of in-river operations, and modification of the remedial operation, Control Level monitoring requirements will commence unless otherwise instructed by USEPA.

- Routine monitoring will resume in the Lower Hudson after non-routine monitoring has confirmed that the concentrations in the Lower Hudson are below 350 ng/L Total PCBs and the estimated concentration at Waterford and Troy have fallen below 350 ng/L Total PCBs for at least two days.

- When suspended solids criteria are exceeded, the suspended solids concentrations must fall below the action level for one day before USEPA may approve a reduction in the level of monitoring and the contingencies can be relaxed.

During temporary halting of in-river remedial operations, routine monitoring of the Upper River far-field stations will continue. If the operations are temporarily halted, monitoring in the Lower Hudson will continue at non-routine frequency until the requirements listed above are met.

4.4 Special Studies

The monitoring programs for the resuspension and residual standards are organized to separate sampling necessary to measure compliance with the standard from sampling efforts needed to evaluate and refine the implementation of the standard. This has been accomplished by designating the second category of sampling efforts as “special studies.” The special studies will be conducted for limited periods of time to gather information for specific conditions that may be encountered during the remediation or to develop an alternate strategy for monitoring. Specific conditions may include different dredge types, contaminant concentration ranges, and varying sediment textures. Each of these studies is integral to the Phase 1 evaluation, the development of Phase 2, and is also tied to compliance issues.

There are a total of five special studies for the resuspension standard. These are as follows:

- Near-field PCB Release Mechanism (Near-field PCB Concentrations)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Full Scale)
- Non-Target, Downstream Area Contamination
- Phase 2 Monitoring Plan

The main components of each of these studies is described below.

4.4.1 Near-Field PCB Concentrations

A special study will be conducted in the near field to characterize the nature of PCB release due to dredging-related activities, specifically to evaluate whether the PCB release due to these activities occurs as the result of dissolved-phase or suspended-matter phase releases. Data from this study will be used to evaluate the use of suspended solids as a useful surrogate to identify PCB releases. Suspended solids will be a useful predictor of PCB exceedances if the nature of the release is primarily resuspension of suspended-phase PCBs. Following are some of the specifics that pertain to the Near-Field PCB Concentrations Study.

4.4.1.1 Duration

Each study will last for a full work week (six or seven days) in each selected area. The duration for the study of debris removal may be reduced if the debris removal is completed in less than a week.

4.4.1.2 Sample Collection

The study will entail daily sample collection for each study area during the week of investigation. This should allow for the collection of a sufficient number of samples to distinguish dredging-related conditions from variations in the water column due to baseline conditions.

The sampling locations will be arrayed in two transects located 100 ft and 200 ft downstream of the dredge and will also include one upstream location. If there is containment around the dredge, one composite sample consisting of three discrete locations will be collected from within the containment and the transects will be located just downstream of the containment and 100 ft downstream.

Each transect will contain five sample locations. If the water depth is greater than 10 ft, two samples will be collected from each location (0 to 10 ft and deeper than 10 ft). A sample will also be collected from a station 50 ft upstream from the dredge. Figure 1-1 depicts the layout of the monitoring stations. The location of the sampling stations may be adjusted with the approval of the USEPA’s field coordinator.

The plume will be identified at the transect locations using ADCP. This will be done with a second boat that will continuously monitor for the location of the plume during the sample collection. The signal from the ADCP increases markedly once the edge of the plume is encountered.

4.4.1.3 Sample Handling

Vertically integrated samples will be collected following EDI techniques to represent the area around the dredge (not the entire river width) and composited. Each sample (comprised of several vertically integrated sampling nodes) will be filtered in the field as soon as possible from the time of collection. Filtering of the sample must be completed within two hours of collection. Samples will be collected in separate bottles at each substation for each parameter measured. No samples will be split.

4.4.1.4 Analytical and Direct Reading Methods

The following parameters will be measured on each sample:

- PCB congener analysis (dissolved and suspended phases)
- Suspended organic carbon
- Dissolved organic carbon
- Suspended Solids

Turnaround times must be assigned to allow sufficient amount of time to meet the reporting requirements.

Measurements with a probe will be made at each substation for:

- Turbidity
- Temperature
- pH
- Conductivity
- Laser-based particle size distribution

All measurements will be analytically consistent with the far-field monitoring program.

4.4.1.5 Definition of the Study Areas

Near-field total PCBs will be measured at several locations to determine the nature of PCB releases for different sediment types (cohesive and non-cohesive), concentration ranges, and dredge types. A near-field study will also be conducted during at least one debris removal event.

Table 4-6 summarizes the possible areas for special study in the near field to characterize the nature of PCB release due to dredging-related activities. The areas were chosen based on:

- Type of sediment as classified by the side scan sonar.
- Type of sediment as classified by ASTM Method D422.
- Range of Tri+ PCB entire core length weighted averages (LWAs) concentration.

Draft dredge area boundaries were used to guide the selection of the possible study areas. (Note that these dredge area boundaries have not been approved by the USEPA; however, while the boundaries have not been approved, the identified locations are expected to be included in the final delineation of dredge areas and so were identified for this special study.) Figure 4-4 shows the possible study areas, sediment type as classified by side scan sonar, and the Tri+ PCB LWA range. Figure 4-5 shows the possible study areas and different types of sediment as classified by ASTM Method D422. Of the 13 possible study areas depicted, 5 areas are recommended for the special study (Table 4-7). Selection of these 5 study areas did not take into consideration other engineering factors and the type of equipment that will be used for dredging; therefore, the final selection of study areas may be different. The final selection of the study areas will be determined upon USEPA approval of the *Phase I Intermediate Design Report*.

4.4.2 Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement For the Near-Field and Far-Field Stations (Bench Scale)

Laboratory studies correlating the direct measurement of suspended solids (i.e., TSS analyses) and turbidity-based field measurements (or another surrogate real-time measure of suspended solids) are required such that the near-field and the far-field suspended solids analyses can be replaced with a surrogate real-time measure of suspended solids. The need for a real-time measurement is evident from the sample frequency analysis, which demonstrates that given the variability in baseline suspended solids concentrations, samples will be collected every 15 minutes to monitor a suspended solids release with sufficient confidence. This can only be achieved with a direct reading field measurement device. These analyses will provide a link between the direct but time-consuming measurement of suspended solids and surrogate suspended solids measurements, which can be performed continuously and remotely with the use of a buoyed monitoring station (or another equivalent method for the far-field stations).

4.4.2.1 Near Field

The relationship between suspended solids concentrations and turbidity for the Hudson River Remediation is expected to be an evolving one, with the relationship potentially changing over time as different sediments and hydrodynamic conditions are encountered. Additionally, near-field requirements will be different due to the stronger suspended solids and turbidity signals near the dredge operation. The concerns dictate the need for separate study goals appropriate to near-field and far field conditions. It also necessitates the need to review and revise the relationships as new field data are obtained.

For these reasons, the initial near-field suspended solids bench scale study must focus on the sediments of the Phase 1 target areas. Subsequently, the daily sampling of near-field TSS along with turbidity must be used to verify the initial relationship or slowly modify the relationship.

4.4.2.2 Far-Field

The development of a surrogate for suspended solids in the far-field must also be included in this special study. At a distance of 1 mile from the dredge, it will be difficult to discern a simple increase in suspended solids concentration due to dredging given the baseline variability and the small increase of concern (12 to 24 mg/L). To this end, the far-field monitoring will include laser-based particle counters or equivalent to provide data on the distribution of particle sizes in the water column in addition to the turbidity monitors. The distribution of particle sizes due to dredging is expected to be quite different from baseline, due in part to the different fractions of organic matter in the sediments *vs.* normal water column conditions. Based on these observations, it should be possible to discern a rise in TSS approaching the threshold due to baseline variability from a rise due to dredging resuspension. The combination of increased suspended solids concentrations and turbidity along with a change in particle size distribution should provide the most accurate signal of dredging-related releases and the need to sample. Given this approach, it will also be necessary to collect data on the natural range of particle size distributions under baseline prior to dredging (as part of baseline monitoring).

4.4.2.3 Study Procedures

The procedures to do this study are described in guidance from the US Army Corps of Engineers (Thackston and Palermo, 2000). Both the USACE Long Tube Settling Test and batch tests as per Earhart (1984) will be conducted. However, the procedures involving long tube settling tests for compression are not needed, which should reduce the time required for the study.

4.4.2.4 Selection of Sediment Characteristics for the Study

Hudson River sediments will be collected from a number of locations in each river section to encompass the range of sediment types that will be encountered while dredging. This range of samples should provide a basis to examine the relationship between direct measurement of suspended solids and turbidity measurements and permit turbidity to serve as a surrogate of suspended solids measurement for a broad range of sediment types.

This study will characterize the response for a minimum of three sediment types (silt, fine sand and medium sand) by collecting at least 8 separate samples of each sediment class. Samples must have median diameters consistent with their intended class (*e.g.,* silt must fall between 5 and 75 um median diameter) and have that class as the major fraction in the sample.

4.4.2.5 Duration

A typical bench scale test can be conducted within a week. The initial study will be conducted prior to the beginning of Phase 1. Subsequent bench scale tests may be conducted if a surrogate measurement fails to predict suspended solids concentrations with sufficient accuracy. See Section 4.4.3 for more information.

4.4.3 Develop and Maintain of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement For the Near-Field and Far-Field Stations (Full Scale)

This special study addresses the means by which the surrogate relationship for suspended solids will be evaluated and updated using the confirmatory sample data. Surrogate relationships for the near-field and far-field monitoring stations will be developed initially using only laboratory methods as described above. It is expected, however, that field samples of TSS and estimates based on the surrogate relationship will deviate somewhat from the laboratory-based relationships. Thus, it is necessary to continually review and revise the relationships as new field data are obtained. At first, the evolution will transition the relationship to represent field conditions. However, these relationships are expected to evolve throughout the program as different sediment and hydrodynamic conditions are encountered.

Daily confirmatory samples will be collected at near-field and far-field stations under normal conditions. If there is an exceedance of the suspended solids-based resuspension criteria, the rate of confirmatory sampling increases to two per day at the station with the exceedance. These daily samples will be used to verify the initial relationship and eventually modify it. Over time, the daily monitoring requirements should provide a large data set with which to examine and establish a field-specific suspended solids-turbidity relationship.

Statistical approaches will be used to evaluate data as it is collected, determine if the TSS-Turbidity relationship should be modified, and refine the relationship based upon the new data. This assessment will be conducted separately for the near-field and far-field surrogate relationships.

Statistical Assessment

To verify that the surrogate relationship from the field data does not deviate significantly from the initial relationship developed in the laboratory, statistical tests need to be performed. Additionally, as the data set of field measurements grows, the combined field and laboratory data can be combined into a single data for the purposes of defining the relationship. The following statistical tests may be used:

- Examine the proportion of the field data that falls within the 95 percent confidence bounds of the predictive relationship . The confidence bounds are those for the prediction interval from the regression. The confidence interval for an individual point prediction, y_0, is given by:

$$y_0 \pm \frac{t_{n-2}}{\sqrt{n-2}} s_{y.x} \sqrt{\frac{n+1+n(x_0-\bar{x})^2}{s_x^2}}$$

where:

y_0 = individual measured total suspended solids (TSS) concentration of the field sampling,
n = number of paired TSS and surrogate measurement pairs of the laboratory-based data,
x_0 = individual turbidity value,
$\bar{x}$ = average predicted TSS concentration estimated from the regression,

s_x^2 = variance of predicted TSS concentration estimated from the regression,

t_{n-2} = approximately 1.96 for 95 percent confidence intervals and large sample size (Normal approximation),

$s_{y.x}$ = standard deviation of the TSS, given by $\sqrt{\frac{\sum\left(TSS_{predictied} - TSS_{field}\right)^2}{n}}$

where:

$TSS_{predicted}$ = predicted TSS concentration estimated from the regression,

TSS_{field} = measured TSS concentrations.

The above equation will give the fraction of measured suspended solids concentrations that fall within the 95 percent confidence limits of the regression. If more than 10 percent of the measured suspended solids concentrations data fall outside the 95 percent confidence limits, it is considered to be a poor fit.

- Chow's F test (Fisher, 1970) can test whether the parameters for two data sets (e.g., the initial laboratory data versus a collection of field measurements) are significant. It requires calculating the error sum of squares or sum of squared residuals (SSEs) for regression models on each of the data sets individually and an SSE for a regression on the pooled data. The comparison is made by forming an F statistic with k and (t_1+t_2-$2k$) degrees of freedom, formed as (Kennedy, 1979):

$$F = \frac{[SSE(constrained) - SSE(unconstrained)]/k}{SSE(unconstrained)/(t_1 + t_2 - 2k)}$$

where

SSE(unconstrained) = the sum of the *SSE*s from the two separate regressions,

SSE(constrained) = the *SSE* from the regression of the pooled data,

$SSE = \sum\left(Y - \hat{Y}\right)^2$

Where: Y = measured TSS concentrations and

$\hat{Y}$ = predicted TSS concentrations.

t_1 = the number of observations in the first sample set,

t_2 = the number of observations in the second sample set, and

k = the number of parameters in the model, including the intercept term.

The resulting statistic can then be compared to a tabulation of the *F* distribution with *k* and (*t1+ t2 - 2k*) degrees of freedom to test the hypothesis that parameters have changed significantly between data sets 1 and 2. If the calculated F statistic exceeds the critical value F, the null hypothesis (no change in the regression lines) can be rejected. An *F* statistic with a 95 percent probability of occurring can be considered indicative of a significant difference in the parameters, and by inference, a difference between the laboratory and field relationships.

- Theil's U statistic that gives a measure of the consistency between the forecasts (e.g., field data predictions using the initial surrogate relationship model) and the data used to develop the forecasts. It ranges from 0 to 1, with 0 indicating perfect predictions. The variance of the U statistics can be approximated (for U less than 0.3) as U^2/T, where T is the number of samples in the "forecast." The U statistic is defined as (Pindyck and Rubinfeld, 1981):

$$U = \frac{\sqrt{\frac{1}{T}\sum (Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{T}\sum (Y_t^s)^2} + \sqrt{\frac{1}{T}\sum (Y_t^a)^2}}$$

where

Y_t^s	=	simulated TSS value for observation t,
Y_t^a	=	actual TSS value of the observation t, and
T	=	total number of observations.

The numerator of *U* is simply the root mean square simulation error, but the scaling of the denominator is such that *U* always falls between 0 and 1. The U statistics may also be decomposed into portions attributed to bias or systematic error (U^m), variance or ability of the model to replicate the degree of variability in the variable of interest (U^s), and covariance or unsystematic error (U^c). These *proportions of inequality*, which sum to 1, are defined as:

Bias Error
$$U^m = \frac{(\bar{Y}^s - \bar{Y}^a)^2}{(1/T)\sum (Y_t^s - Y_{t^a}^a)^2}$$

Variance Error
$$U^s = \frac{(\sigma_s - \sigma_a)^2}{(1/T)\sum (Y_t^s - Y_{t^a}^a)^2}$$

Covariance Error
$$U^c = \frac{2(1-\rho)\sigma_s \sigma_a}{(1/T)\sum (Y_t^s - Y_t^a)^2}$$

where:

$\bar{Y}^s$ = the mean of the series of the simulated TSS Y_t^s,

$\bar{Y}^a$ = the mean of the series of actual TSS Y_t^a,

σ_s = the standard deviation of the series Y_t^s,

σ_a = the standard deviation of the series Y_t^a,

ρ = the correlation coefficient of the two series.

When U is non-zero, a desirable evaluation of a model will show that the non-zero component is dominantly attributable to the covariance or unsystematic component, which represents non-controllable random variability. Weight on the bias component indicates that the linear relationship differs between the two data sets. Weight on the variance component indicates that the difference is attributable primarily to differing variances between the two data sets.

For the purposes of the TSS-turbidity relationship, consistency in the relationship would be exhibited by a high U^c component and low values for U^m and U^s. Values of U^m and U^s over 0.2 are indicative of a significant difference between the laboratory and field relationships.

Low Bias Assessment

In addition to the statistical tests, the measured suspended solids concentration data need to be checked for low bias compared to the surrogate regression. If 75 percent of the measured suspended solids data falls under the regression for 4 days out of 7 days, it is recommended that the surrogate relationship be reassessed.

Evaluation

The statistical tests and the comparison of the field data to the current surrogate relationship need to be performed daily. The frequency of assessing the data may be lowered in Phase 2, if appropriate. Data from confirmation suspended solids sampling collected during the previous seven days (if applicable to current operating conditions) will be compared to the data used to develop and maintain the surrogate relationship. This data will initially be composed initially of the bench scale test results. When Phase 1 begins and confirmatory samples for suspended solids are collected, these results will be compared to the bench scale results in the manner described below.

- If Chow's F, Theil's U and the low bias assessments, show the surrogate relationship to be in compliance, continue use of the surrogate for evaluation of the suspended solids based resuspension standard.

- If Chow's F or Theil's U statistics fail, and there is no low bias, the surrogate relationship is in compliance, but the data from the previous day should not be used to reassess the current regression. It is recommended that the regression be reassessed.

- If Chow's F or Theil's U statistics fail, and there is no low bias, the surrogate relationship is not in compliance. It is required that the regression be reassessed.

The regression will be re-evaluated weekly to capture the information from the field results and adjust the means of calculating the suspended solids concentrations from the surrogate. Daily measurements will be evaluated in terms of the existing relationship.

Reassessment of the Surrogate Relationship

In the event that the reassessment of the surrogate relationship is needed, there are two options. Sediment in the current area could be collected and a bench scale study that conforms to the special study described in Section 4.4.2 could be conducted. This method is preferred. Alternatively, the confirmatory samples for suspended solids can be assessed to determine if a revised surrogate measurement can be derived from the available data. Until a revised surrogate regression can be derived and approved by USEPA, samples will be collected every three hours for suspended solids analysis with three hour turnaround (using the modified method for suspended solids) and used for compliance with the standard. This sampling will apply to either the near-field or the far-field, depending on which surrogate relationship needs reevaluation.

4.4.3.1 Duration

This study will be conducted throughout Phase 1. It is likely that this study will be maintained in some form throughout the remediation, because the surrogate relationships are likely to require adjustment as the remediation moves throughout the river.

4.4.4 Phase 2 Monitoring Plan

This study will be conducted to demonstrate the feasibility and implementability of alternated monitoring programs that are proposed for Phase 2 of the remediation. The study will determine if the alternate program fully meets the data quality objectives defined for the Resuspension Standard monitoring program. The results of the study will be used to adjust the resuspension criteria, monitoring program and engineering contingencies for the Phase 2 standard.

4.4.4.1 Definition of the Study Areas

The Phase 2 Monitoring Program would need to be implemented at all stations where changes to the Phase 1 Montioring Program are proposed.

4.4.4.2 Duration

The Phase 2 monitoring plan must be implemented for enough time to allow potential problems with the alternate sampling methods to be identified. The program must be in use during the month of full production, but the extent to which the duration of the study will extend beyond that period will depend on the details of the Phase 2 monitoring plan.

Alternate monitoring programs with more challenging aspects may require longer periods of implemention.

4.4.4.3 Assessment of Data

The data acquired during this study will be compare to the results of the Phase 1 monitoring program to determine if the alternate program succeeds in achieving the data quality objectives defined for the Phase 1 program. The study will be reviewed to determine if there are implementation issues that require alteration. The reliability of the alternate program will be assessed.

4.4.4.4 Automatic Samplers for PCB Sample Collection

An alterative to the Phase 1 monitoring plan that may be contemplated would be use of automatic sampling devices to collect the PCB samples under routine conditions. Once a fuller understanding of the nature of contaminant release is acquired through the monitoring program as written is acquired, a well designed monitoring that included the use of automatic samplers for collection of the PCBs could conceivably be of benefit providing more temporal coverage and may reduce costs.

Specific Requirements

While conceptually reasonable, there are aspects associated with the use of automatic samplers that may make implementation difficult. For instance:

- How will these samplers be maintained to ensure that samples are always being collected and the instruments have not clogged?
- If piping is needed, how will the integrity of the pipes be maintained?
- If piping is needed, how will the system be designed to avoid settling of suspended mater in the pipe?
- How will the samplers be decontaminated between samples?
- How will the samplers be protected from boat traffic and still collect representative samples from the cross-section?

Some specific requirements of an alternate monitoring program that includes automatic samplers are:

- The stations must be in the same location as the baseline monitoring program,.
- Samples must be collected in a manner that is compliant with EDI or EWI.
- The reliability of the system must be demonstrated.
- Decontamination procedures must be demonstrated.
- A comprehensive maintenance plan must be developed.

Resultant Changes to the Standard

Use of automatic samplers to collect PCBs may prompt changes to other aspects of the standard. The resuspension criteria, aspects of the near-field and far-field monitoring program and engineering contingencies would need to be evaluated.

The higher sampling frequency that can be achieved with composite sampling would provide a more reliable measurement of the water column concentration. Assuming that the issues identified above can be overcome, there would be more certainty in these measurements and the period in which an exceedance of the resupsension criteria can be known would be reduced. Table 4-8 shows a possible revision to the resuspension criteria should PCB samples be collected with automatic samplers. The time period for each PCB-based resuspension criteria has been reduced from seven days to time periods of two to four days, which are derived from considerations of statistical certainty. The engineering contingencies and monitoring contingencies associated with these exceedances would need to be re-evaluated. The time frames for implementation of engineering contingencies would also need to be re-evaluated.

If the Phase 2 Monitoring Program demonstrated that this means of sampling were acceptable, alterations would be made to the Phase 2 Resuspension Standard criteria in light of the information acquired during Phase 1.

4.4.5 Non-Target, Downstream Area Contamination

This study will examine the amount of resuspended material that has settled in the local downstream areas of the dredging operation and could act as a potential source of future contamination of the water column and downstream surficial sediment. The primary data quality objective for this study is to determine the extent of contamination in terms of spatial extent, concentration and mass of Tri+PCB contamination deposited downstream from the dredged target areas in non-target areas.

The data acquired from this study will be used to determine if the resuspension controls are adequately limiting downstream transport of contamination. A basis for this determination may be a comparison to the thresholds for MPA and surface concentrations provided in the ROD. If the local downstream areas are exceeding these criteria, the resuspension controls will require evaluation. Another consideration will be the amount of mass that is transported downstream near the bottom of the river.

4.4.5.1 Definition of the Study Areas

Study areas will be identified in the same manner as the Near-Field PCBs special study (Section 4.4.1.5). The study area will cover approximately five acres. In addition to these specifications, the area downstream area will not be rock or gravel as defined by the side scan sonar. Because these areas will be located in the Phase 1 dredge zones, the areas that are sampled may not be non-target areas as defined by the dredge line delineations, but will be studied to have this information early on in the project.

4.4.5.2 Duration

The studies will be conducted throughout Phase 1.

4.4.5.3 Sampler Deployment and Collection

Sediment traps or equivalent equipment will be deployed in the study area. Sediment traps will be deployed at the rate of eight per five-acre area. The sediment traps will be laid out on a triangular grid. The sediment traps will be co-located (approximately 10 ft apart). This will allow one of the co-located sediment traps to be sampled each week, while the other remains in place for the duration of the study and is sampled at the end. The sediment traps will be installed at the start of the dredging in the area under study.

4.4.5.4 Sample Handling

Suspended sediments collected in the trap will be weighed to determine mass collected and then homogenized for subsequent organic carbon and PCB analysis. PCB analysis for the short deployment traps may not be possible if a limited mass of sediment is obtained.

4.4.5.5 Analytical Methods

The following parameters will be measured on each sample:

- Sediment mass collected
- Organic carbon content
- PCB congener analysis

The following field measurements will be recorded:

- Date and time of deployment
- Date and time of sample collection
- Depth of sediment in the sediment trap
- Approximate distance from the dredge operation.

All measurements will meet or exceed the analytical specifications for the SSAP program.

4.4.5.6 Definition of the Study Areas

The areas to be studied will be identified in a similar manner to the Near-Field PCBs special study (Section 4.4.1.). Each study area will cover approximately five acres downstream from an area undergoing remediation. In addition to these specifications, the downstream study area will not include rock or gravel as defined by the side scan sonar, since these are generally poor depositional zones and unlikely to accumulate sediment from the dredge. Because these areas will be located downstream of the Phase 1 dredge zones, the areas that are sampled may not be non-target areas as defined by the dredge line delineations. This is not a concern since the Phase 1 downstream areas are typically depositional and should provide a conservative estimate of the amount of deposition that can occur over non-target areas.

4.4.6 Further Development of the Special Studies

The special studies will be further developed and specific implementation details documented in work plans and quality assurance project plans developed during the design phase. Modification of some aspects of the special studies as outlined may be permissible as long as the objectives of the studies can be achieved. All modifications to the programs as outlined in this document will require USEPA review and approval.

4.5 Engineering Contingencies

For the Hudson River remediation, engineering contingencies must be considered for the dredging operation if the action levels are exceeded:

Engineering contingencies must be considered for the dredging operation if the action levels are exceeded.

- Engineering contingencies will be recommended for consideration when the Evaluation Level is exceeded by any measure (*i.e.*, suspended solids or PCBs, near-field or far-field).

- Engineering contingencies will be required and implemented if the Total PCB or Tri+ PCB concentrations exceed the Control Level or the Resuspension Standard (500 ng/L Total PCBs), based on monitoring results at the far-field stations for PCB load- or concentration-based criteria, not suspended solids criteria.

- If the Control Level or the Resuspension Standard threshold is exceeded, an adjustment to the remedial operation is mandatory.

- If the Evaluation Level, the lower tier action level, is exceeded, an adjustment to the operation is optional.

Additional monitoring is mandatory when any of the action levels criteria parameter (*i.e.*, Total PCBs, Tri+ PCBs, or suspended solids) is exceeded. Engineering evaluations of the source of the exceedance are also required when the Control Level or the Resuspension Standard threshold is exceeded.

The performance standard requires increased monitoring contingencies, engineering evaluations, and modification of remedial operations for exceedance of the action levels. Subsections 4.2 and 4.3 describe the monitoring contingencies. This section describes the engineering evaluations, suggested technologies to control resuspension, and the requirements of the standard in this regard. These engineering evaluations and technologies are described in general terms here, but will be specified during the remedial design and possibly modified during the remedial operation.

Recommended and required engineering contingencies are listed below for each action level and the Resuspension Standard threshold.

- **Evaluation Level**
  - Evaluate and identify any problems.
  - Examine boat traffic patterns near the dredges.
  - Examine sediment transfer pipelines for leaks.
  - Recommend engineering evaluations near the dredges and barges.
  - Perform other such engineering evaluations as appropriate.
  - Recommend PCB sample collection in the near-field or other areas of the operation as a part of an engineering evaluation.

- **Control Level**
  - Initiate mandatory engineering evaluation and continual adjustments to dredging operations until the Evaluation Level or better is attained.
  - Evaluate and identify any problems.
  - Consider change in resupension controls, dredge operation, or dredge type.
  - Consider implementing additional resuspension controls.
  - Consider changing location and rescheduling more highly contaminated areas for later in the year (applies to May and June only), if all other options are not effective.
  - Temporarily cease operations if required.

- **Resuspension Standard**
  - Mandatory cessation of all operations in the river is required if Total PCB concentration levels in excess of 500 ng/L Total PCBs are confirmed by next day's samples.
  - Restart requires engineering evaluation and USEPA approval.

4.5.1 Timeframe for Implementing Engineering Evaluations and Engineering Improvements

The time frame for the initiation and completion of engineering evaluations and implementation of the engineering solutions must be specified as part of the remedial design. The actual implementation schedule in the field is subject to USEPA review and oversight. It is anticipated that engineering evaluations will begin immediately upon receipt of data indicating the exceedance of a criterion. It is similarly anticipated that the required engineering contingencies should begin as soon as possible so as to minimize PCB releases. At a minimum, engineering contingency actions should begin within a week of an exceedance, assuming conditions remain in exceedance. In the case of a temporary halt of the operations, an evaluation should be completed with five days. In the event of a temporary cessation, every effort should be made to correct the problem and minimize the length of time of the stoppage.

4.5.2 Engineering Evaluations

Engineering evaluations are required for exceedance of the Control Level and Resuspension Standard and recommended but not required for exceedance of the Evaluation Level.

The engineering evaluation includes the study of all dredge-related operations and supporting components, including review of the dredging operation, barrier installation, and sediment transportation system. Engineering evaluations are required for exceedance of the Control Level and Resuspension Standard and recommended but not required for exceedance of the Evaluation Level.

Exceedance of the suspended solids criteria must be confirmed by PCB measurements before actions other than increased monitoring are required. The evaluation and review of the dredging operation should include additional turbidity measurements in the vicinity of the dredge, barge, pipeline, etc., and will be conducted to evaluate the possible source(s) and mechanism(s) causing the exceedance. An engineering evaluation will include the following as needed:

- Examination of the containment barrier, if it is in use, for leaks and stability
- Examination of the sediment transport pipeline, if a hydraulic dredge is used
- Examination of the barge loading system and barge integrity, if barges are used
- Examination of the turbidity associated with the sediment transport barges and other support vehicles
- Analysis of near-field water column samples for Total PCBs, as well as analysis of samples from other locations such as along the sediment transport pipeline, the channel, etc.

The evaluation will be briefly documented in a report with approach, results, and conclusions for submittal to USEPA. Submittal of a report is mandatory in cases where USEPA must approve modifications to the remediation or give approval to resume operations following temporary halting of remedial operations.

4.5.3 Implementation of Control Technologies

This subsection discusses engineering contingencies recommended for consideration in the event of an exceedance of the Control Level or Resuspension Standard. The contingencies consist of implementation of specific control technologies and apply to remedial operations. A more detailed description of these technologies is provided in Attachment E to the Resuspension Standard. Use of these contingencies resulted primarily from the review of relevant case studies (See Volume 5) and from research done during preparation of the Hudson River FS Report (USEPA, 2000b).

4.5.3.1 Remedial Operations

Barriers and modifications to operations and equipment are the principal and most useful methods for reducing the suspended solids and PCB concentrations downstream of the dredging operation.

Barriers

Barrier types reviewed in Attachment E include:

- Fixed structural barriers such as sheet piling.
- Non-structural barriers such as silt curtains and silt screens.
- Portable barriers systems such as the Portadam™ and Aqua-Barrier™ systems.
- Air bates.
- Control zone technology.

If a barrier system has been implemented, but action levels are still exceeded, further steps that can be considered include the following:

- Monitor or inspect the barrier for leaks
- Identify and correct problems with the installation
- Change the barrier material to a more effective material such as high density polyethylene (HDPE)
- Install multiple layers of barriers
- Fasten the barrier to the river bottom

Operation and Equipment Modifications

Operation and equipment modifications that may reduce the generation of suspended sediments include:

- Limiting/reducing boat speeds to reduce prop wash.
- Restricting the size of boats that can be used in certain areas.
- Loading barges to less than capacity where necessary to reduce draft.
- Use of smaller, shallow draft boats to transport crew members and inspection personnel to and from the dredges.

- Selection of an alternate dredge with a lower resuspension rate.
- Selection of another means of placing backfill/capping materials.
- Scheduling changes to the dredge plan/pattern to avoid remediation of highly contaminated areas during times of year when background PCB concentrations are high (applies to May and June only).

4.5.4 Requirements of the Standard

The standard provides a series of action levels by which the severity of the dredging-related release can be measured and quantified. As an action level is exceeded, engineering evaluations and engineering solutions will be suggested or required, based on the level of the exceedance. This tiered level of enforcement is set up to allow for the remediation to be conducted continuously without operation near the Resuspension Standard threshold, thus avoiding subsequent temporary halting of remedial operations due to a confirmed exceedance.

In summary, the Resuspension Standard requires the following:

Action Level	Monitoring Contingencies Required*	Engineering Evaluation Required	Engineering Contingencies Required
Evaluation	Yes	Recommended	No
Control	Yes	Yes	Yes
Resuspension Standard Threshold	Yes	Yes	Yes

* Monitoring requirements for suspended solids exceedances limited for the far-field monitoring to only one or two stations, in order to capture the PCB concentrations in the impacted water column.

4.5.5 Settled Contaminated Material and the Need for Resuspension Barriers

The near-field modeling results presented in subection 2.6 and Attachment D indicate that a substantial amount of the suspended solids will settle in the immediate vicinity of the dredge. In particular, coarse-grained sediments settle very rapidly and so will most likely be captured by a subsequent dredging pass. However, fine-grained sediments may remain in the water column sufficiently long to settle beyond the areas selected to be dredged.

While modeling analysis does not show these additions to be significant in terms of long-distance transport, the redeposited sediments may potentially create small regions of elevated contamination just outside the remedial areas. This could elevate the PCB concentration of the river bed surficial sediments downstream of the remediation to concentration levels that are unacceptable even for the least stringent PCB load-based action level (300 g/day).

The potential for redeposition leads to the conclusion that, where appropriate, resuspension barriers of some type should be considered to contain the resuspended material within the target areas and control the spread of contaminated material.

The potential for redeposition indicates that, where appropriate, resuspension barriers should be considered.

The need for these controls is suggested by evidence obtained from the dredging on the Grasse River. Rising concentrations of cesium-137 and PCB in the surface layer sediment downstream were observed as part of the post-dredge sampling of the Grasse River non-time critical removal action (NTCRA). As shown in Figure 4-6, cesium-137 increases in the uppermost layers of all four cores collected downstream of the dredging operation. The surface layer sediment represents the most recently deposited material. In term of natural variation, the concentration for cesium-137 is not expected to increase since its source (atmospheric weapons testing) no longer exists. This significant increase is consistent with the release and redeposition of older sediments containing high levels of cesium-137 as a result of dredging operations. The relatively thin layer suggests this is not a significant redeposition on the scale of miles (the distance among the cores) but does demonstrate its occurrence.

PCBs do not show as much response as Cesium 137 in the Grasse River sediment, but evidence of a recent PCB release is clear in one core (18M). This core shows significantly elevated PCB concentrations at the surface, also consistent with a suspended solids release. The elevated PCB levels associated with this core may also reflect the generally higher PCB levels in recently deposited sediments, suggesting that the location may collect more of the fine-grained, PCB-contaminated sediments than the other coring locations. Notably, the triple silt barriers used at this site were not fastened to the river bottom, potentially permitting resuspended material to travel beneath them and move downstream. While these data cannot be construed as proof, this does do suggest that suspended solids settling estimates warrant further consideration. Some form of sediment monitoring outside the target areas will be required. Sediment monitoring for this purpose is required in one of the special studies discussed previously, the Non-Target Area Contamination study.

These data also suggest that dredging should generally proceed from upstream to downstream, or the associated redeposition will recontaminate remediated areas. Where resuspension barriers are used, the water flow rate within the barriers is expected to be greatly reduced, thereby significantly reducing this problem.

Dredging should generally proceed from upstream to downstream, or the associated redeposition will recontaminate remediated areas.

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Additional references are provided in the attachments.

Tables

Table 1-1
Resuspension Criteria[1]

Parameter		Resuspension Standard Threshold		Control Level[2]		Evaluation Level	
		Limit	Duration	Limit	Duration	Limit	Duration
Far-Field PCB Concentration	Total PCBs	500 ng/L	Confirmed Occurrence [8]	350 ng/L	7-day running average		
Far-Field Net PCB Load[3]	Total PCBs			65 kg/year[4]	Dredging Season		
	Tri+ PCBs			22 kg/year[4]			
	Total PCBs			600 g/day	7-day running average	300 g/day	7-day running average
	Tri+ PCBs			200 g/day		100 g/day	
Far-Field Net Suspended Solids Concentration[5,6]	All Sections			24 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	12 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
Near-Field (300 m) Net Suspended Solids Concentration[7]	Sections 1 & 3			100 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	100 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
	Sections 2			60 mg/L		60 mg/L	
Near-Field (100 m and Channel-Side) Net Suspended Solids Concentration[7]	All Sections					700 mg/L	3 continuous hrs. running average.

Notes:
1. Implemention of the criteria is described in Section 3.
2. Engineering contingencies for the Control Level will include temporary cessation of the operation.
3. Net increases in PCB load or suspended solids concentration refers to dredging related releases over baseline as defined in the text.
4. During Phase 1, half of the anticipated average production rate will be achieved. As a result, the total allowable export for Phase 1 is half of the fullscale value of 130 kg/year for a total of 650 kg for the entire program. This is equivalent to the 600 g/day Total PCB release at the target productivity schedule, during the dredging season from May to November. The Tri+ PCB values are 22 kg/year for Phase 1, 44 kg/year for full scale production and 220 kg for the entire program.
5. The increased far-field monitoring required for exceedance of suspended solids criteria must include a sample timed so as to capture the suspended solids plume's arrival at the far-field station.
6. The monitoring requirements for exceedance of the suspended solids action levels are increased frequency sampling at the nearest far field station. The increased frequency at this station will be the same as the frequency required for the PCB action levels.
7. All remedial operations will be monitored in the near-field during Phase 1, including backfilling.
8. Exceedance of the Resuspension Standard must be confirmed by the 4 samples that are collected once a concentration greater than 500 ng/L Total PCB is detected. The average of the 5 sample concentrations is compared to the Resuspension Standard. The Resuspension Standard is exceeded if the average

Table 1-2
Sampling Requirements on a Weekly Basis - Upper River Far-Field Stations

Routine Monitoring Number of Samples per Week	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses: Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	TSS (1/3-hours)_	Integrating Sampler for PCBs	Probe: Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	7	7.5	7.5	56	0.5	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_	24	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 181.4 - Schuylerville_	24	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
Samples/Week		36	38.5	38.5	280	2.5			
PCB analyses/week		**38.5 or 5.5 /day**							

Evaluation Level Number of Samples per Week	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses: Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)_	Integrating Sampler for PCBs	Probe: Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	7	7.5	7.5	56	0.5	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_	24	14	14.5	14.5	56	0.5	Continous	Discrete	None
RM 181.4 - Schuylerville_	24	14	14.5	14.5	56	0.5	Continous	Discrete	None
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
Samples/Week		50	52.5	52.5	280	2.5			
PCB analyses/week		**52.5 or 7.5 /day**							

Control Level Number of Samples per Week	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses: Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	TSS (1/3-hours)_	Integrating Sampler for PCBs	Probe: Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	7	7.5	7.5	56	0.5	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_	24	21	22	22	56	1	Continous	Discrete	None
RM 181.4 - Schuylerville_	24	21	22	22	56	1	Continous	Discrete	None
RM 163.5 - Stillwater_	24		7	7	56	7	Continous	Discrete	None
RM 156.5 – Waterford_	24		7	7	56	7	Continous	Discrete	None
Samples/Week		50	66.5	66.5	280	16.5			
PCB analyses/week		**66.5 or 9.5 /day**							

Threshold[4] Number of Samples per Day Only	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses: Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	TSS (1/3-hours)_	Integrating Sampler for PCBs	Probe: Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	1	1	1	8	1/2-weeks	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_,_	24	4	5	5	8	1	Continous	Discrete	None
RM 181.4 - Schuylerville_,_	24	4	5	5	8	1	Continous	Discrete	None
RM 163.5 - Stillwater_	24	4	5	5	8	1	Continous	Discrete	None
RM 156.5 – Waterford_	24	4	5	5	8	1	Continous	Discrete	None
Samples/day		18	22	22	40	4			
PCB analyses/day		**22 /day**							

Note:

1. TI Dam and Schuylerville will be representative stations while the dredging is ongoing in the Phase 1 areas and will be sampled more intensely. Samples will be composited from hourly grab samples for theResuspension Standard threshold at these two stations.

2. TSS sampling every 3- hours will be required for compliance at the nearest representative far-field stations only if the semi-quantative relationship between TSS and a surrogate is not sufficiently conservative (See Section 4). Samples collected at the other stations will have 12-hour turnaround.

3. The turnaround time for PCB analyses from the integrating sampler will only be specified when the information is needed quickly for comparison to the resuspension criteria. For the Resuspension Standard the integrating sample turnaround times will be 24-hours for the two representative far-field stations (TI Dam and Schuylerville stations) and 72-hours for the stations farther downstream (Stillwater and Waterford stations). For the Control Level at Stillwater and Waterford, the turnaround times will be 72-hours and 24-hours, respectively.

4. The monitoring for the Resuspension Standard threshold is required for one day only for verification of the elevated concentration.

5. Continuous laser particle analysis is required only ar the nearest far-field station to the dredge operation. For the purpose of this table, the Phase-1 area was assumed to occur in the TIP

Table 1-3
Sampling Requirements on a Weekly Basis - Lower River Far-Field Stations

Lower River Sampling Requirements on a Weekly Basis

Routine Monitoring [1]	Lab Turn-Around Time (hr.)	Laboratory Analyses			Probe	
		Congener-specific PCBs Whole Water	DOC & Susp. OC	SS	Turbidity, Temp., pH, Cond.	Dissolved Oxygen
Mohawk River at Cohoes	72	0.25	0.25	0.25	0.25	0.25
RM 140 - Albany	72	0.25	0.25	0.25	0.25	0.25
RM 77 - Highland	72	0.25	0.25	0.25	0.25	0.25
Samples/Week		0.75	0.75	0.75	0.75	0.75

Non-Routine Monitoring [2]	Lab Turn-Around Time (hr.)	Laboratory Analyses			Probe	
		Congener-specific PCBs Whole Water	DOC & Susp. OC	SS	Turbidity, Temp., pH, Cond.	Dissolved Oxygen
Mohawk River at Cohoes	24	1	1	1	1	1
RM 140 - Albany	24	1	1	1	1	1
RM 77 - Highland	24	1	1	1	1	1
Samples/Week		3	3	3	3	3

Notes:
1. Routine monitoring samples for the Lower Hudson stations are collected once per month.

Table 1-4
Sampling Requirements on a Weekly Basis - Upper River Near-Field Stations

Near-Field Sampling Requirements on a Weekly Basis [1, 2, 3, 4]
Routine Monitoring (Use of continuous reading probe to indicate suspended solids concentrations.)

No. of Operations	No. of SS Laboratory Analyses [5] per week	No. of Discrete Measurements by Laser Particle Counter per week	No. of Continuous Monitors
1	35	35	5
2	70	70	10
3	105	105	15
4	140	140	20
5	175	175	25
6	210	210	30
7	245	245	35
8	280	280	40
9	315	315	45
10	350	350	50

Non-Routine Monitoring (If the surrogate analysis fails to predict TSS concentrations adequately.)[1, 5, 6]

No. of Operations	Number of SS Laboratory Samples with 3-Hour Turn-Around, per Week					Discrete Probe Measurements for Turbidity & Laser Particle Counter (No. per week)
	Number of Stations (where surrogate is out of compliance)				All Stations[7]	
	1	2	3	4	5	
1	49	98	147	196	245	35
2	98	196	294	392	490	70
3	147	294	441	588	735	105
4	196	392	588	784	980	140
5	245	490	735	980	1,225	175
6	294	588	882	1,176	1,470	210
7	343	686	1,029	1,372	1,715	245
8	392	784	1,176	1,568	1,960	280
9	441	882	1,323	1,764	2,205	315
10	490	980	1,470	1,960	2,450	350

Notes:
1. A surrogate must be established to determine compliance with the TSS based resuspension criteria. Only if this surrogate relationship fails to adequately predict TSS concentrations will sampling for TSS concentrations every 3-hours with a 3-hour turnaround be required. If compliance is based on TSS samples, 1 sample will be collected an hour prior to beginning of the operation and at least 3 samples will be collected at 1-hour intervals after completing for the day.
2. One TSS samples will be collected per day per station to confirm the surrogate semi-quantitative relationship.
3. If a TSS resuspension criteria is exceeded at a monitoring station, two TSS samples will be collected per day at that station to confirm the surrogate semi-quantitative relationship.
4. Turbidity, temperature, pH, conductivity and dissolved oxygen will be monitored continuously at each of the five near-field stations.
5. Assumed hours of operation: 14 hours of dredging per 24 hours of operation per day for the quantities above.
6. Exceedence of a suspended solids criteria will also prompt monitoring at the representative far-field station nearest to the location of the exceedence at the frequency of sampling indicated for the action level.
7. If containment is used in an area, 6 stations will be required, increasing the total

Table 1 - 5
Case Study Resuspension Summary Table

Project/Site Name	Dates of Operation	Project Setting	Water Quality Parameters Monitored	Water Quality Standard	Water Quality Monitoring Stations	Water Quality Measurements Reported During Dredging
Fox River: Kimberly, Wisconsin Deposit N	November 1998 to December 1998 (Phase I); August 1999 to November 1999 (Phase II)	Riverine	Turbidity, TSS, and PCBs	Turbidity - Threshold limit based on hourly average value; Specific threshold not stated in materials reviewed; PCBs- water column concentrations compared to pre-dredge concentrations and upstream samples versus downstream samples compared-specific threshold not indicated	Real time turbidity monitoring at 6 stations: (1) upstream, (1) side gradient, (1) downstream, (1) at ILP water intake, (1) at the ILP effluent discharge, and (1) within the contained dredge area. Measured turbidity at 50% total water depth	Average PCB water column concentration during Phase I (1998) downstream of dredging was 11 ng/L compared to an average upstream measured concentration of 3.2 ng/L during dredging. Baseline concentration before Phase I was 5.0 ng/L. Average downstream PCB concentration during Phase II (1999) was 24 ng/L compared to an average upstream PCB concentration of 14 ng/L. Minor differences between upstream and downstream turbidity during dredging. No apparent difference in TSS data collected upstream and downstream of the dredge was noted from measurements collected during dredging.
Fox River: Green Bay, Wisconsin SMU 56/57 Phase I	August to December 1999 (Phase I)	Riverine	Turbidity, TSS, and PCBs	Not indicated in documents reviewed	Real time turbidity monitoring at 6 locations: (1) upstream dredge outside turbidity barrier;(1) upstream dredge inside turbidity barrier;(1) side stream dredge outside turbidity barrier;(1) downstream dredge outside turbidity barrier;(1) downstream dredge inside turbidity barrier; (1) at Fort James water intake - Each meter located in water column at 50-60% of the water depth for location	Average PCB water column concentration downstream of the dredge was 90 ng/L compared to an upstream concentration of 51 ng/L during dredging and a baseline concentration prior to dredging of 52 ng/L. Turbidity monitors downstream of the dredge, outside the silt curtain were indicative of periodic turbidity increases. TSS samples only showed minor differences between the upstream and downstream locations. Monthly averaged turbidity data indicated that a high turbidity of 41 NTU occurred during the first month of dredging (August) downstream of the dredge, outside the silt curtain.
Fox River: Green Bay, Wisconsin SMU 56/57 Phase II	August 2000 to November 2000 (Phase II)	Riverine	Turbidity, TSS, and PCBs	Turbidity - Reached threshold if downstream turbidity reading was two or more times higher than the upstream reading and cause was related to dredging; Specific PCB threshold not indicated in documents reviewed	Real time turbidity monitoring at 3 locations: (1) upstream of silt curtain at the Fort James water intake; (1) 10-ft downstream of the silt curtain; and (1) 50-ft downstream of the silt curtain	Upstream and downstream turbidity values never varied by more than a factor of two during dredging. Contractor did not perform PCB water column monitoring since turbidity threshold was neve exceeded however PCB water column sampling was performed by the USGS.
Manistique River, Michigan	1995 - 1999	Riverine	Turbidity, TSS, and PCBs	TSS concentration less than 2X the background turbidity within 50-feet of the dredge head; Literature reviewed stated that this level was achieved within 10-feet of the dredge head. PCB water quality threshold not stated in literature reviewed. It was noted that PCB concentrations were compared to pre-dredge water column PCB concentrations	For 1997 Dredging: seven samples from one station near dredge; one sample from upstream; six samples from a station downstream; and two samples from a station outside of the dredge area. For 1998: 9 samples from station upstream of dredge; 8 samples from locations downstream of dredge- distance and exact location not specified.	In 1997: avg. PCB water column concentrations outside dredge area was 0.37mg/L and avg. [PCB] downstream of dredge was 0.23 mg/l compared to pre-dredge concentration of 0.001 mg/L. The background sample collected during this event was 0.062 mg/L PCBs. In 1998: Avg. upstream [PCB] was 0.093 mg/L and the average [PCB] downstream was 0.066 mg/L.
Reynolds Metals: St. Lawrence River, Massena. NY	April 2001 through November 2001	Riverine	Turbidity and water column samples (PCBs , PAHs, and PCDFs); TSS was not measured in this project.	Turbidity action level of 25 NTU above the background level, which was derived based on 28 NTU action level used at GM Massena. The action levels for water column samples were 2 ug/L of PCBs, 0.2 ug/L for PAHs and detectable PCDFs above the practical quantitation limit (PQL).	Monitoring was conducted at different locations for each project phase (sheetpile installation, dredging, capping, and sheet pile removal); All locations identified in Final Case Study Table (Appendix A of th Resuspension standard). For dredging: (4) stations outside the sheet piling- one upcurrent (100ft from the active dredge) and 3 down current stations (10, 150 and 300 ft from the sheet pile wall closest to the dredge being monitored). Within the sheetpiling-Water Quality was monitored at 12 to 19 different stations based on dredge location.	Outside the sheet piling : Turbidity during dredging ranged between 0.5 to 1.5 NTUs. During dredging, water column PCB concentrations ranged between 0.05 to 0.53 ug/L. and PAH and PCDF were non-detect in samples analyzed
GM Massena: St. Lawrence River, Massena, NY	May 1995 through December 1995	Riverine	Turbidity, PCBs, PAHs	Action level was selected based on a 1994 site-specific bench-scale laboratory correlation between TSS and turbidity, and experience in previous dredging projects. Downstream turbidity 28 NTUs above background corresponded to a downstream TSS of 25 mg/L above background. For PCBS: 2 ug/L (at downstream monitoring locations)	Visual observations and real-time turbidity monitoring at 3 locations: 50 feet upstream of western extent of control system, two between 200 feet and 400 feet downstream of easternmost active installations. Measurements collected from 50% water depth. Water column sampling at the same two downstream locations as the turbidity measurements.	In 18 out of 923 turbidity samples, the 28 NTU action level was exceeded (31-127 NTU) at 1-ft below the water surface for a duration of 2-8 minutes, on average, however 2 exceedances lasted for 15 minutes and 45 minutes respectively. Exceedance determined to be a result of water overflow from the dredge area over the sheet piling due to inadequate height/installation. PCBs monitored at same station as turbidity. High PCB concentrations correlated with times where high turbidity (> 28 NTU) measured. Filtered [PCB] ranged between 0.94-2.4 ug/L and unfiltered ranged between 4.51 to 9.84 ug/L. These PCB measurements collected at end of Phase I after sheet piling removed.
Cumberland Bay: New York	April 1999 to May 2000	Western side of Lake Champlain	TSS, turbidity and PCB	Turbidity was used only to alert the operators of a potential re-suspension problem-not associated with an action level.**Operational Monitoring**: TSS 25 mg/L above background. **Compliance Monitoring** (outside turbidity barrier): TSS 4 mg/L above background. When TSS action level was exceeded, dredging was suspended or modified.	**Operational Monitoring**: Real-time turbidity monitoring in 2 locations: on dredge head and using a float that trailed behind the dredge. **Compliance Monitoring:** Four OBS-3 sensor stations which changed for each active work zone: one sensor in a background location (near breakwater) and three sensors outside the perimeter of the work zone silt curtain (an additional temporary sensor was located near Georgia-Pacific's industrial water intake). **Documentation Monitoring:** Six fixed turbidity monitoring (TM) buoys (in 1999 outside perimeter turbidity curtain; 2000 locations different).	Documentation reviewed indicated that the TSS levels were not exceeded and dredging was never suspended.
United Heckathorn: Parr Canal and Lauritzen Channel on the San Francisco Bay	August 1996 through March 1997	Bay area - shipping inlet/slip	TSS and Contaminants of Concern: DDT and Dieldrin	Surface water: Dieldrin 0.14ng/L and DDT 0.59ng/L both based on EPA AWQ (Ambient water Quality criteria) and also based on human health standards (risk)	Four water quality sampling stations- Locations were established both upstream and downstream of area being dredged and downstream/outside channel/ship inlet/slip in the harbor and bay at both ends	Data not available in documents reviewed for water quality data during dredging however it was noted that the area is extremely turbid naturally due to ship traffic; Post-dredge water quality data collected 4-months after dredging indicated concentrations equal to or greater than predredge conditions. This was a result of incomplete dredging near banks and around structures. Dredging not a success at this site and further action to be taken.

Table 1 - 5
Case Study Resuspension Summary Table

Project/Site Name	Dates of Operation	Project Setting	Water Quality Parameters Monitored	Water Quality Standard	Water Quality Monitoring Stations	Water Quality Measurements Reported During Dredging
Grand Calumet River, Indiana	Dredging Began November 2002 (currently in progress)	Riverine	Level 1: Flow, total ammonia, specific conductance, DO, pH, sulfides, temp., and turbidity monitored daily by multi-parameter automatic data logger system; Level 2: microtox chemical testing for acute and chronic toxicity; Level 3: chemical monitoring for total ammonia, pH, sulfides, temp, free cyanide, hardness oil and grease, TSS, dissolved aluminum, dissolved copper, dissolved lead, total mercury, dissolved zinc, select VOCs, and total PCBs; Each Level Monitoring is conducted concurrently at a pre-set frequency. A contingency plan exists for each Level monitoring in the event that a high measurement is recorded.	IDEM (Indiana Department of Environmental Management) chronic and acute state surface water criteria	(1) upstream background sampling location; (1) located near mid-channel 200-yd downstream from open water dredge; (1) downstream sampling site below 5-mile dredge area; (1) proposed sample location for verification analysis located 200-yd upstream of open water dredging in cell c	Data Not yet available; dredging currently underway
New Bedford Harbor (Hot Spots), New Bedford, Massachusetts	April 1994 to September 1995	Estuary/Bay	PCBs (24-hr turn-around) and metals. PCBs (Total PCBs: dissolved and particulate tested separately and summed).	PCBs: 1.3 mg/L determined by a pilot study and a Maximum cumulative transport (MCT) of PCBs during the entire operation of 240 Kg PCBs.	Down current locations: 50 ft, 300 ft, 700 ft, and 1,000 ft. from dredging area. Background measurements: ~ 1,000 ft up-current of dredging operations. Sampling depth: ~ mid-depth in the water column.	By the end of project, a total PCB transport of 57 kg was reported. Thus, the MCL was not exceeded. Toxicity tests completed during dredging were not indicative of acute toxicity and PCB accumulation in mussels was not significantly greater then predredge measurements.
New Bedford Harbor (Pre-Design Field Test), New Bedford, Massachusetts	Demonstration Project in August 2000	Estuary/Bay	TSS, turbidity and PCBs (dissolved and particulate, PCB congeners)	PCBs: No set limit since background concentrations exceeded Federal criteria however did set the maximum Cumulative Transport (MCT) for PCB loss from dredging at the limit of mixing zone (300 ft from the dredge) of 400 kg PCBs throughout entire dredging project. Turbidity: 50 NTU above background at limit of mixing zone (300 ft from the dredge)	2 Monitoring stations 300 ft away from dredge; additional sampling as required 600 ft from dredge. Background measurements ~ 1,000 ft up-current of dredging operations.	Turbidity measurements exceeded the 50 NTU threshold infrequently at the 300-ft limit of the mixing zone and no further action was taken. Bioassay tests completed when turbidity exceeded 50 NTU were not indicative of an ecological impact.
Commencement Bay: Hylebos Waterway	Small hot spot dredging October 2002; Full-scale dredging begun 2003	Tidal Waterway	Turbidity and dissolved oxygen (system currently exhibits a low dissolved oxygen level and managers do not want dredging to deplete it any further)	It is anticipated that the turbidity standard will be set at either 20 NTU or 50 NTU over background.	2 anticipated monitoring stations; one near dredge head and one at the limit of the mixing zone (300-ft from the dredge)	Data not yet available.
Commencement Bay: Thea, Foss, Wheeler, Osgood Waterway	Full-scale dredging begun 2003	Tidal Waterway	Turbidity however water quality monitoring plan still in design	It is anticipated that the turbidity standard will be set at either 20 NTU or 50 NTU over background.	2 anticipated monitoring stations; one near dredge head and one at the limit of the mixing zone (300-ft from the dredge)	Data not yet available.

Table 2-1
Summary of Case Studies for PCB Losses Due to Dredging

Project	Period of Dredging	Total PCBs Removed (kg)	Total PCBs Resuspension Loss (kg)	Percentage Lost (%)
GE Hudson Falls Dredging	Oct.-Dec. 1997, Aug.-Nov. 1998	3,890	14	0.36%
New Bedford Harbor Hot Spots	1994-1995	43,700	57	0.13%
Fox River Deposit N	Nov. - Dec. 1998 (Phase I) Aug. -Dec.1999 (Phase II)	111	4.20	3.5% - 14% (1)
Fox River SMU 56/57	Aug. - Nov. 1999 (Phase I)	1,490	22	2.2% (2)

Notes:
(1) Average Daily Percentage Loss varied over dredge season based on dredge location and uncertainty associated with PCB removal estimation.
(2) PCB Percentage Loss based on USGS study while other values taken from the SMU 56/57 Final Summary report (September 2001).

Table 2-2
Far-Field Forecast Model Runs Completed for the Performance Standard

Scenario [5]	Description	Rate of PCB Release [1] g/day (kg/yr) [3]	Period of Dredging	Start Year	Completed Simulations [4] Upper Hudson HUDTOX	FISHRAND	Lower Hudson Farley	FISHRAND
-	MNA	NA	-	-	x	x	x	x
-	No resuspension	0 (0)	6	2004	x	x	x	x
d004	No resuspension	0 (0)	6	2006	X	X	X	X
-	2.5% Export[2]	1,700 (350)	6	2004	x	x	x	x
sr01	300 g/day	300 (70)	6	2006	X	X	X	X
sr02	600 g/day	600 (130)		2006	X	X	X	X
sr04	350 ng/L	1,600 (340)	6	2006	X	X	X	X
-	Accidental Release	600 (130)	6	2006	X			

Notes:

1. All PCB resuspension scenarios were based on a resuspension release rate (near-field release) at the specified percentage of dredging loss unless noted otherwise.
2. The model run included with the Responsiveness Summary for the ROD is effectively a 2.5 percent export scenario since all PCBs were loaded as dissolved phase. See text for further discussion.
3. The rates are based on 7 months of operation, 7 days per week at 14 hours per day.
4. x = completed for ROD
   X = completed for this report
5. The d004 and sr01 and sr04 and sr0x series of scenarios were created during the development of the performance standards.

Table 2-3
Upper Hudson Conceptual Dredging Schedule

Sediment removal season	Dredging Location	Speed of operation
May 1 - Nov. 1, 2006	Sec. 1	half
May 1 - Nov. 30, 2007	Sec. 1	full
May 1 - Nov. 30, 2008	Sec. 1	full
May 1 - Aug. 15, 2009	Sec. 1	full
Aug. 16 - Nov. 30, 2009	Sec. 2	full
May 1 - Aug. 15, 2010	Sec. 2	full
Aug. 16 - Nov. 30, 2010	Sec. 3	full
May 1 - Aug. 15, 2011	Sec. 3	full

Table 2-4
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				350 ng/L (sr04)			
	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
1998	3.317	6.813	9.271	1.537	3.316	6.807	9.276	1.537
1999	3.328	6.908	9.406	1.510	3.328	6.909	9.410	1.509
2000	2.866	5.747	8.346	1.300	2.865	5.751	8.338	1.300
2001	2.582	5.098	7.588	1.177	2.583	5.104	7.585	1.177
2002	2.370	4.841	6.925	1.053	2.372	4.848	6.924	1.054
2003	2.182	4.340	6.471	0.978	2.182	4.338	6.474	0.978
2004	2.290	5.285	6.356	0.946	2.290	5.286	6.354	0.946
2005	1.905	3.912	5.712	0.816	1.911	3.910	5.740	0.821
2006	1.617	2.996	5.119	0.716	1.703	3.111	5.350	0.770
2007	1.487	2.838	4.669	0.647	1.709	3.461	5.141	0.739
2008	1.297	2.318	4.226	0.571	1.673	3.762	4.743	0.694
2009	0.964	1.573	2.949	0.489	1.323	2.317	3.769	0.687
2010	0.595	0.899	1.355	***0.398***	0.928	1.012	1.835	0.753
2011	0.447	0.661	0.847	0.332	0.817	0.736	1.122	0.781
2012	0.404	0.723	0.786	0.269	0.631	0.774	0.999	0.537
2013	***0.342***	0.568	0.717	0.229	0.515	0.600	0.883	0.433
2014	0.318	0.593	0.669	***0.199***	0.453	0.602	0.803	***0.361***
2015	0.289	0.520	0.638	0.178	***0.400***	0.524	0.751	0.312
2016	0.294	0.586	0.651	0.170	0.391	0.589	0.750	0.287
2017	0.296	0.671	0.612	0.161	0.379	0.672	0.704	0.260
2018	0.272	0.606	0.574	0.149	0.344	0.605	0.665	0.233
2019	0.281	0.710	0.567	0.140	0.341	0.702	0.656	0.210
2020	0.243	0.584	0.502	0.125	0.292	0.579	0.584	***0.180***
2021	0.217	0.471	0.482	0.117	0.260	0.468	0.557	0.164
2022	0.215	0.476	0.477	0.114	0.253	0.473	0.548	0.155
2023	0.216	0.529	0.454	0.108	0.247	0.524	0.514	0.142
2024	***0.195***	0.484	0.417	0.094	0.219	0.480	0.463	0.122
2025	0.176	0.415	***0.391***	0.088	***0.196***	0.413	0.426	0.110
2026	0.163	***0.357***	0.377	0.084	0.180	0.355	0.405	0.103
2027	0.183	0.490	0.380	0.083	0.197	0.488	0.403	0.100
2028	0.177	0.509	0.353	0.076	0.189	0.508	***0.371***	0.090
2029	0.158	0.414	0.337	0.072	0.168	0.412	0.351	0.084
2030	0.143	0.326	0.326	0.072	0.152	***0.325***	0.342	0.082
2031	0.151	0.422	0.303	0.067	0.159	0.421	0.320	0.075
2032	0.138	0.362	0.288	0.064	0.145	0.362	0.305	0.071
2033	0.133	0.349	0.277	0.061	0.138	0.349	0.295	0.066
2034	0.132	0.368	0.259	0.060	0.134	0.368	0.276	0.060
2035	0.123	0.279	0.249	0.068	0.116	0.279	0.266	0.056
2036	0.148	0.356	0.242	0.087	0.124	0.356	0.258	0.051
2037	0.137	0.297	0.234	0.086	0.115	0.298	0.250	0.053
2038	0.140	0.337	0.221	0.083	0.130	0.337	0.235	0.068
2039	0.128	0.270	0.214	0.083	0.132	0.271	0.227	0.087
2040	0.124	0.262	0.214	0.079	0.132	0.262	0.225	0.087
2041	0.140	0.359	0.219	0.079	0.150	0.360	0.228	0.091
2042	0.143	0.400	0.223	0.074	0.153	0.401	0.229	0.087
2043	0.123	0.318	0.202	0.068	0.132	0.318	0.206	0.080
2044	0.108	0.245	***0.191***	0.064	0.114	0.246	***0.193***	0.073
2045	0.112	0.282	0.190	0.063	0.118	0.283	0.191	0.070

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-4
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

	No Resuspension (d004)				350 ng/L (sr04)			
Year	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
2046	0.105	0.258	0.184	0.058	0.109	0.256	0.184	0.064
2047	0.109	0.284	0.187	0.058	0.112	0.271	0.187	0.065
2048	0.115	0.329	0.188	0.057	0.118	0.318	0.187	0.064
2049	0.116	0.339	0.190	0.055	0.120	0.340	0.189	0.062
2050	0.105	0.289	0.183	0.052	0.109	0.290	0.182	0.057
2051	0.101	0.286	0.180	***0.047***	0.104	0.287	0.178	0.052
2052	0.094	0.244	0.181	0.047	0.097	0.246	0.180	0.051
2053	0.113	0.359	0.187	0.048	0.116	0.359	0.185	0.052
2054	0.105	0.311	0.185	0.047	0.107	0.311	0.184	0.050
2055	0.098	0.274	0.182	0.045	0.100	0.274	0.180	***0.048***
2056	0.105	0.307	0.195	0.046	0.106	0.307	0.193	0.048
2057	0.105	0.323	0.185	0.045	0.107	0.324	0.183	0.047
2058	0.095	0.253	0.188	0.045	0.096	0.253	0.186	0.047
2059	0.109	0.356	0.181	0.043	0.110	0.356	0.181	0.045
2060	0.091	0.256	0.175	0.040	0.092	0.256	0.175	0.042
2061	0.086	0.234	0.169	0.040	0.087	0.233	0.169	0.042
2062	0.091	0.261	0.171	0.040	0.091	0.261	0.170	0.042
2063	0.091	0.261	0.172	0.041	0.091	0.260	0.171	0.041
2064	0.093	0.268	0.175	0.041	0.093	0.268	0.174	0.042
2065	0.092	0.255	0.178	0.043	0.093	0.255	0.177	0.043
2066	0.105	0.353	0.172	0.041	0.105	0.353	0.171	0.041
2067	0.095	0.275	0.180	0.042	0.095	0.275	0.179	0.042

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-4
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

Year	600 g/day (sr01)				Monitored Natural Attenuation			
	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
1998	3.316	6.807	9.276	1.537	3.353	6.774	9.659	1.529
1999	3.328	6.909	9.410	1.509	3.212	6.621	8.877	1.501
2000	2.865	5.751	8.338	1.300	2.791	5.563	8.028	1.292
2001	2.583	5.104	7.585	1.177	2.504	4.924	7.210	1.171
2002	2.372	4.848	6.924	1.054	2.301	4.705	6.571	1.047
2003	2.182	4.338	6.474	0.978	2.129	4.290	6.090	0.980
2004	2.290	5.286	6.354	0.946	2.204	5.084	5.934	0.942
2005	1.908	3.909	5.726	0.819	1.852	3.739	5.523	0.812
2006	1.666	3.076	5.237	0.746	1.574	2.890	4.904	0.716
2007	1.614	3.225	4.920	0.697	1.474	2.862	4.489	0.654
2008	1.525	3.216	4.582	0.634	1.371	2.774	4.168	0.586
2009	1.106	1.907	3.140	0.583	1.262	2.616	3.877	0.519
2010	0.707	0.943	1.411	0.535	1.116	2.321	3.533	0.440
2011	0.568	0.697	0.901	0.483	0.971	1.921	3.164	***0.388***
2012	0.469	0.747	0.818	***0.350***	0.878	1.851	2.879	0.324
2013	***0.389***	0.572	0.734	0.291	0.791	1.682	2.601	0.287
2014	0.353	0.582	0.675	0.248	0.742	1.666	2.396	0.258
2015	0.316	0.506	0.638	0.219	0.686	1.535	2.229	0.237
2016	0.317	0.573	0.648	0.205	0.680	1.610	2.126	0.231
2017	0.315	0.660	0.610	***0.190***	0.649	1.573	1.978	0.221
2018	0.289	0.595	0.577	0.173	0.593	1.437	1.765	0.210
2019	0.295	0.694	0.572	0.161	0.577	1.497	1.619	***0.200***
2020	0.253	0.571	0.507	0.142	0.512	1.270	1.480	0.182
2021	0.226	0.459	0.486	0.131	0.460	1.080	1.365	0.171
2022	0.222	0.464	0.482	0.126	0.450	1.093	1.296	0.166
2023	0.222	0.517	0.461	0.118	0.435	1.088	1.225	0.158
2024	***0.200***	0.474	0.427	0.102	***0.385***	0.939	1.123	0.139
2025	0.181	0.406	0.402	0.094	0.350	0.842	1.019	0.129
2026	0.166	***0.347***	***0.388***	0.089	0.325	0.757	0.952	0.124
2027	0.186	0.483	0.387	0.088	0.339	0.888	0.920	0.121
2028	0.179	0.504	0.353	0.080	0.322	0.863	0.875	0.111
2029	0.159	0.407	0.332	0.076	0.287	0.720	0.801	0.105
2030	0.143	0.320	0.322	0.075	0.261	0.620	0.735	0.103
2031	0.152	0.418	0.302	0.069	0.257	0.679	0.675	0.095
2032	0.139	0.357	0.289	0.066	0.234	0.602	0.610	0.091
2033	0.133	0.343	0.279	0.063	0.219	0.560	0.564	0.086
2034	0.132	0.366	0.261	0.059	0.208	0.545	0.521	0.082
2035	0.114	0.275	0.251	0.055	***0.191***	0.443	0.475	0.089
2036	0.125	0.352	0.244	0.055	0.209	0.504	0.446	0.104
2037	0.125	0.295	0.237	0.070	0.190	0.427	0.410	0.101
2038	0.140	0.335	0.224	0.083	0.189	0.456	***0.386***	0.098
2039	0.131	0.268	0.218	0.087	0.173	0.382	0.363	0.096
2040	0.128	0.260	0.217	0.085	0.164	0.352	0.346	0.092
2041	0.146	0.358	0.222	0.087	0.180	0.461	0.347	0.092
2042	0.148	0.399	0.225	0.081	0.178	0.486	0.337	0.084
2043	0.129	0.320	0.205	0.075	0.155	***0.386***	0.316	0.078
2044	0.114	0.256	***0.195***	0.069	0.136	0.301	0.289	0.074
2045	0.118	0.301	0.194	0.066	0.137	0.329	0.278	0.071

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-4
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

Year	600 g/day (sr01)				Monitored Natural Attenuation			
	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
2046	0.110	0.273	0.187	0.062	0.131	0.319	0.269	0.067
2047	0.112	0.285	0.190	0.062	0.153	0.474	0.261	0.066
2048	0.116	0.316	0.190	0.061	0.175	0.612	0.263	0.066
2049	0.117	0.328	0.192	0.059	0.166	0.574	0.259	0.063
2050	0.106	0.283	0.185	0.055	0.151	0.498	0.251	0.060
2051	0.104	0.294	0.182	***0.050***	0.140	0.457	0.242	0.055
2052	0.099	0.263	0.184	0.049	0.130	0.402	0.236	0.054
2053	0.118	0.379	0.189	0.050	0.146	0.494	0.244	0.055
2054	0.109	0.327	0.187	0.049	0.134	0.430	0.235	0.053
2055	0.101	0.287	0.183	0.047	0.125	0.383	0.231	0.052
2056	0.108	0.322	0.195	0.047	0.129	0.407	0.233	0.051
2057	0.108	0.337	0.186	0.046	0.126	0.397	0.231	0.050
2058	0.097	0.264	0.188	0.046	0.116	0.337	0.226	0.050
2059	0.111	0.366	0.182	0.044	0.127	0.422	0.228	***0.047***
2060	0.093	0.266	0.175	0.041	0.106	0.316	0.209	0.044
2061	0.087	0.241	0.169	0.041	0.100	0.286	***0.200***	0.043
2062	0.092	0.268	0.170	0.041	0.102	0.297	0.197	0.043
2063	0.092	0.266	0.171	0.041	0.101	0.296	0.196	0.043
2064	0.094	0.273	0.175	0.042	0.103	0.306	0.196	0.044
2065	0.093	0.260	0.177	0.043	0.100	0.283	0.195	0.045
2066	0.106	0.358	0.171	0.041	0.113	0.377	0.195	0.043
2067	0.096	0.279	0.179	0.043	0.101	0.301	0.183	0.044

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-5

Modeled Years-of-Compliance with Human Health Risk-Based Concentrations for Various Resuspension Scenarios

	No Resuspension (d004)	350 ng/L (sr04)	600 g/day (sr01)	MNA
Upper River Average				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	2024	2025	2024	2035
Fish Target Concentration 0.4 mg/kg	2013	2015	2013	2024
River Section 1- RM 189				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.4 mg/kg	2026	2030	2026	2043
River Section 2- RM 184				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	2044	2044	2044	2061
Fish Target Concentration 0.4 mg/kg	2025	2028	2026	2038
River Section 3- RM 154				
Human Health RG 0.05 mg/kg	2051	2055	2051	2059
Fish Target Concentration 0.2 mg/kg	2014	2020	2017	2019
Fish Target Concentration 0.4 mg/kg	2010	2014	2012	2011

Note: RG = risk-based remediation goal
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-6
Estimated Non-cancer Indices via Long Term Fish Ingestion for Several Resuspension scenarios-
Adult Angler and Upper Hudson Fish

Remedial Alternative	PCB Conc. in Fish (mg/kg ww)	Intake (Non-Cancer) (mg/kg-day)	Reference Dose (mg/kg-day)	Hazard Index
Reasonable Maximum Exposure				
Upper Hudson Average				
No Resuspension d004	0.30	1.4E-04	2.0E-05	6.9
350 ng/L sr04	0.58	2.6E-04	2.0E-05	13
600 g/day sr01	0.50	2.3E-04	2.0E-05	11
MNA	1.4	6.4E-04	2.0E-05	32
River Section 1 (RM 189)				
No Resuspension d004	0.62	2.8E-04	2.0E-05	14
350 ng/L sr04	0.64	2.9E-04	2.0E-05	15
600 g/day sr01	0.62	2.8E-04	2.0E-05	14
MNA	1.7	7.7E-04	2.0E-05	39
River Section 2 (RM 184)				
No Resuspension d004	0.66	3.0E-04	2.0E-05	15
350 ng/L sr04	0.79	3.6E-04	2.0E-05	18
600 g/day sr01	0.67	3.1E-04	2.0E-05	15
MNA	2.3	1.0E-03	2.0E-05	52
River Section 3 (RM 154)				
No Resuspension d004	0.18	8.0E-05	2.0E-05	4.0
350 ng/L sr04	0.30	1.4E-04	2.0E-05	6.8
600 g/day sr01	0.21	9.7E-05	2.0E-05	4.8
MNA	0.23	1.1E-04	2.0E-05	5.4
Central Tendency				
Upper Hudson Average				
No Resuspension d004	0.27	1.2E-05	2.0E-05	0.6
350 ng/L sr04	0.52	2.4E-05	2.0E-05	1.2
600 g/day sr01	0.46	2.1E-05	2.0E-05	1.0
MNA	1.2	5.5E-05	2.0E-05	2.8
River Section 1 (RM 189)				
No Resuspension d004	0.60	2.7E-05	2.0E-05	1.4
350 ng/L sr04	0.61	2.8E-05	2.0E-05	1.4
600 g/day sr01	0.59	2.7E-05	2.0E-05	1.4
MNA	1.50	6.9E-05	2.0E-05	3.5
River Section 2 (RM 184)				
No Resuspension d004	0.59	2.7E-05	2.0E-05	1.4
350 ng/L sr04	0.70	3.2E-05	2.0E-05	1.6
600 g/day sr01	0.60	2.7E-05	2.0E-05	1.4
MNA	1.9	8.7E-05	2.0E-05	4.4
River Section 3 (RM 154)				
No Resuspension d004	0.15	6.8E-06	2.0E-05	0.3
350 ng/L sr04	0.24	1.1E-05	2.0E-05	0.5
600 g/day sr01	0.18	8.0E-06	2.0E-05	0.4
MNA	0.21	9.4E-06	2.0E-05	0.5

Notes: The RME non-cancer exposure time frame is seven years, while the CT time frame is 12 years.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%;
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-7
Estimated cancer Indices via Long Term Fish Ingestion for Several Resuspension scenarios-
Adult Angler and Upper Hudson Fish

Remedial Alternative	PCB Conc. in Fish (mg/kg ww)	Intake (Cancer) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)	Cancer Risk
Reasonable Maximum Exposure				
Upper Hudson Average				
No Resuspension d004	0.18	4.6E-05	2	9.3E-05
350 ng/L sr04	0.32	8.3E-05	2	1.7E-04
600 g/day sr01	0.30	7.7E-05	2	1.5E-04
MNA	0.60	1.7E-04	2	3.3E-04
River Section 1 (RM 189)				
No Resuspension d004	0.43	1.1E-04	2	2.2E-04
350 ng/L sr04	0.43	1.1E-04	2	2.2E-04
600 g/day sr01	0.42	1.1E-04	2	2.2E-04
MNA	0.86	2.2E-04	2	4.5E-04
River Section 2 (RM 184)				
No Resuspension d004	0.36	9.3E-05	2	1.9E-04
350 ng/L sr04	0.40	1.0E-04	2	2.1E-04
600 g/day sr01	0.36	9.4E-05	2	1.9E-04
MNA	0.90	2.4E-04	2	4.9E-04
River Section 3 (RM 154)				
No Resuspension d004	0.09	2.4E-05	2	4.8E-05
350 ng/L sr04	0.12	3.2E-05	2	6.4E-05
600 g/day sr01	0.10	2.7E-05	2	5.3E-05
MNA	0.12	3.2E-05	2	6.4E-05
Central Tendency				
Upper Hudson Average				
No Resuspension d004	0.27	2.1E-06	1	2.1E-06
350 ng/L sr04	0.52	4.0E-06	1	4.0E-06
600 g/day sr01	0.46	3.6E-06	1	3.6E-06
MNA	1.2	9.5E-06	1	9.5E-06
River Section 1 (RM 189)				
No Resuspension d004	0.60	4.7E-06	1	4.7E-06
350 ng/L sr04	0.61	4.8E-06	1	4.8E-06
600 g/day sr01	0.59	4.7E-06	1	4.7E-06
MNA	1.5	1.2E-05	1	1.2E-05
River Section 2 (RM 184)				
No Resuspension d004	0.59	4.7E-06	1	4.7E-06
350 ng/L sr04	0.70	5.5E-06	1	5.5E-06
600 g/day sr01	0.60	4.7E-06	1	4.7E-06
MNA	1.9	1.5E-05	1	1.5E-05
River Section 3 (RM 154)				
No Resuspension d004	0.15	1.2E-06	1	1.2E-06
350 ng/L sr04	0.24	1.9E-06	1	1.9E-06
600 g/day sr01	0.18	1.4E-06	1	1.4E-06
MNA	0.21	1.6E-06	1	1.6E-06

Notes: The RME cancer exposure time frame is 40 years, while the CT time frame is 12 years.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%;
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-8
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				Total PCB 350 ng/L (sr04)			
	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)
1998	7.13	16.73	17.22	3.33	7.13	16.70	17.24	3.33
1999	7.04	17.11	16.80	3.20	7.04	17.12	16.83	3.20
2000	5.84	13.71	14.51	2.66	5.84	13.74	14.47	2.66
2001	5.29	12.01	13.33	2.47	5.30	12.04	13.32	2.47
2002	4.91	11.63	12.30	2.20	4.92	11.66	12.29	2.20
2003	4.43	10.12	11.39	2.01	4.43	10.11	11.40	2.01
2004	5.12	14.37	11.49	2.04	5.12	14.38	11.48	2.04
2005	3.94	9.68	9.91	1.67	3.95	9.67	9.97	1.68
2006	3.14	6.44	8.80	1.45	3.38	6.61	9.48	1.63
2007	2.96	6.45	8.04	1.33	3.63	8.59	9.25	1.59
2008	2.59	5.37	7.38	1.17	3.88	11.02	8.77	1.51
2009	2.00	4.08	5.15	1.02	3.06	6.90	7.31	1.50
2010	1.35	2.88	2.56	0.81	2.14	3.17	3.68	1.66
2011	1.00	2.02	1.57	0.68	1.94	2.18	2.05	1.86
2012	0.94	2.35	1.48	0.55	1.38	2.45	1.85	1.07
2013	0.76	1.69	1.30	0.47	1.08	1.75	1.59	0.85
2014	0.72	1.80	1.22	0.41	0.97	1.81	1.44	0.71
2015	0.64	1.52	1.16	0.37	0.85	1.53	1.35	0.62
2016	0.68	1.72	1.26	0.36	0.87	1.72	1.43	0.59
2017	0.73	2.17	1.18	0.35	0.89	2.16	1.34	0.54
2018	0.66	1.93	1.09	0.32	0.79	1.91	1.24	0.48
2019	0.72	2.34	1.13	***0.30***	0.83	2.32	1.28	0.43
2020	0.59	1.89	0.92	0.26	0.68	1.86	1.06	0.36
2021	0.51	1.44	0.90	0.25	0.59	1.43	1.03	0.33
2022	0.51	1.43	0.92	0.24	0.58	1.43	1.04	0.33
2023	0.54	1.69	0.88	0.24	0.60	1.67	0.98	0.30
2024	0.49	1.58	0.79	0.20	0.53	1.57	0.87	***0.25***
2025	0.43	1.29	0.74	0.19	0.46	1.29	0.80	0.23
2026	0.38	1.08	0.71	0.18	0.41	1.07	0.75	0.21
2027	0.47	1.60	0.74	0.18	0.50	1.59	0.78	0.21
2028	0.46	1.69	0.65	0.16	0.48	1.69	0.68	0.18
2029	0.39	1.34	0.63	0.15	0.41	1.33	0.65	0.17
2030	0.35	0.99	0.63	0.16	0.36	0.98	0.65	0.18
2031	0.40	1.42	0.58	0.15	0.41	1.41	0.61	0.16
2032	0.35	1.18	0.55	0.14	0.36	1.18	0.58	0.15
2033	0.34	1.14	0.53	0.13	0.35	1.13	0.56	0.14
2034	0.34	1.23	0.49	0.13	0.35	1.23	0.52	0.13
2035	***0.29***	0.88	0.47	0.14	***0.28***	0.87	0.50	0.12
2036	0.40	1.21	0.48	0.22	0.33	1.21	0.50	0.11
2037	0.36	0.98	0.46	0.21	0.29	0.98	0.49	0.11
2038	0.36	1.13	0.43	0.19	0.33	1.13	0.45	0.14
2039	0.33	0.89	0.42	0.19	0.34	0.89	0.44	0.21
2040	0.31	0.86	0.42	0.17	0.33	0.86	0.44	0.20

Notes:
1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-8
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				Total PCB 350 ng/L (sr04)			
	Upper River Average	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**	**Upper River Average**	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**
2041	0.37	1.23	0.44	0.18	0.40	1.23	0.45	0.22
2042	0.39	1.40	0.46	0.16	0.42	1.40	0.47	0.20
2043	0.33	1.10	0.39	0.15	0.35	1.10	0.40	0.18
2044	0.28	0.82	0.37	0.14	0.29	0.82	0.37	0.16
2045	0.30	0.97	0.38	0.14	0.31	0.97	0.38	0.16
2046	0.27	0.86	0.36	0.13	0.28	0.86	0.36	0.14
2047	0.28	0.93	0.37	0.13	0.29	0.91	0.37	0.14
2048	0.30	1.08	0.37	0.13	0.31	1.07	0.37	0.14
2049	0.31	1.14	0.39	0.12	0.33	1.15	0.39	0.14
2050	0.28	0.96	0.36	0.12	0.29	0.96	0.36	0.13
2051	0.27	0.96	0.36	0.10	0.28	0.96	0.36	0.11
2052	0.24	0.80	0.36	0.10	0.25	0.80	0.36	0.11
2053	0.32	1.26	0.38	0.11	0.32	1.26	0.38	0.12
2054	0.29	1.08	0.38	0.11	0.29	1.08	0.38	0.11
2055	0.26	0.93	0.36	0.10	0.26	0.93	0.36	0.11
2056	0.28	1.03	0.41	0.10	0.29	1.02	0.40	0.11
2057	0.29	1.14	0.37	0.10	0.30	1.14	0.37	0.10
2058	0.25	0.85	0.37	0.10	0.25	0.85	0.37	0.10
2059	0.31	1.27	0.36	0.10	0.31	1.26	0.36	0.10
2060	0.24	0.88	0.35	0.09	0.25	0.87	0.35	0.09
2061	0.23	0.79	0.33	0.09	0.23	0.79	0.33	0.09
2062	0.25	0.89	0.34	0.09	0.25	0.89	0.34	0.09
2063	0.24	0.89	0.35	0.09	0.25	0.89	0.34	0.09
2064	0.25	0.92	0.36	0.09	0.25	0.92	0.36	0.09
2065	0.25	0.88	0.36	0.10	0.25	0.87	0.36	0.10
2066	0.30	1.25	0.34	0.09	0.30	1.25	0.34	0.09
2067	0.26	0.95	0.37	0.09	0.26	0.95	0.37	0.09

Notes:
1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-8
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

	Total PCB 600 g/day (sr01)				Monitored Natural Attenuation			
Year	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)
1998	7.13	16.70	17.24	3.33	7.19	16.61	18.04	3.29
1999	7.04	17.12	16.83	3.20	6.76	16.16	15.91	3.17
2000	5.84	13.74	14.47	2.66	5.74	13.09	14.57	2.64
2001	5.30	12.04	13.32	2.47	5.13	11.34	12.94	2.45
2002	4.92	11.66	12.29	2.20	4.76	11.11	11.84	2.18
2003	4.43	10.11	11.40	2.01	4.33	9.92	10.73	2.03
2004	5.12	14.38	11.48	2.04	4.88	13.63	10.57	2.02
2005	3.94	9.67	9.95	1.68	3.85	9.04	10.09	1.66
2006	3.28	6.57	9.17	1.55	3.06	5.97	8.70	1.46
2007	3.35	7.78	8.73	1.47	2.96	6.39	7.95	1.36
2008	3.40	9.02	8.30	1.36	2.78	6.45	7.30	1.21
2009	2.49	5.39	5.93	1.27	2.60	6.16	6.88	1.10
2010	1.65	3.00	2.76	1.17	2.31	5.51	6.40	0.92
2011	1.34	2.12	1.67	1.11	1.95	4.24	5.61	0.83
2012	1.07	2.41	1.54	0.70	1.78	4.21	5.16	0.68
2013	0.85	1.71	1.34	0.59	1.55	3.47	4.60	0.61
2014	0.79	1.80	1.23	0.50	1.46	3.49	4.23	0.55
2015	0.70	1.51	1.16	0.44	1.33	3.13	3.87	0.50
2016	0.73	1.71	1.26	0.43	1.36	3.53	3.65	0.50
2017	0.77	2.16	1.18	0.40	1.38	3.73	3.60	0.49
2018	0.70	1.92	1.10	0.37	1.24	3.29	3.21	0.46
2019	0.75	2.33	1.14	0.34	1.25	3.68	2.94	0.43
2020	0.61	1.87	0.93	***0.29***	1.08	3.02	2.71	0.38
2021	0.53	1.42	0.91	0.27	0.93	2.43	2.40	0.36
2022	0.53	1.42	0.93	0.27	0.93	2.51	2.26	0.36
2023	0.55	1.68	0.89	0.25	0.94	2.67	2.21	0.35
2024	0.50	1.57	0.81	0.21	0.82	2.26	2.05	***0.29***
2025	0.44	1.28	0.76	0.20	0.73	1.98	1.82	0.28
2026	0.39	1.06	0.72	0.19	0.66	1.69	1.68	0.26
2027	0.48	1.59	0.75	0.19	0.75	2.29	1.66	0.27
2028	0.46	1.69	0.66	0.17	0.73	2.33	1.61	0.23
2029	0.40	1.33	0.62	0.16	0.62	1.83	1.44	0.22
2030	0.35	0.98	0.62	0.17	0.55	1.45	1.33	0.23
2031	0.40	1.41	0.58	0.15	0.59	1.86	1.27	0.21
2032	0.35	1.18	0.55	0.14	0.53	1.59	1.13	0.20
2033	0.34	1.13	0.53	0.13	0.49	1.47	1.04	0.18
2034	0.34	1.23	0.49	0.13	0.48	1.50	0.98	0.17
2035	***0.28***	0.87	0.48	0.12	0.41	1.12	0.87	0.18
2036	0.33	1.20	0.48	0.12	0.51	1.43	0.85	0.26
2037	0.32	0.98	0.47	0.15	0.45	1.19	0.75	0.24
2038	0.37	1.13	0.43	0.20	0.45	1.32	0.72	0.22
2039	0.34	0.89	0.42	0.21	0.41	1.09	0.68	0.22
2040	0.32	0.86	0.42	0.19	0.38	0.98	0.63	0.20

Notes:
1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-8
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	Total PCB 600 g/day (sr01)				Monitored Natural Attenuation			
	Upper River Average	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**	**Upper River Average**	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**
2041	0.39	1.23	0.44	0.20	0.45	1.42	0.66	0.21
2042	0.41	1.40	0.46	0.18	0.46	1.56	0.65	0.19
2043	0.34	1.10	0.40	0.16	0.39	1.22	0.62	0.17
2044	0.28	0.83	0.37	0.15	0.32	0.88	0.55	0.16
2045	0.31	1.00	0.38	0.15	0.34	1.04	0.52	0.16
2046	0.28	0.88	0.36	0.14	0.32	0.95	0.51	0.15
2047	0.29	0.93	0.37	0.14	0.35	1.17	0.49	0.15
2048	0.31	1.07	0.37	0.13	0.39	1.42	0.50	0.15
2049	0.32	1.13	0.39	0.13	0.38	1.39	0.50	0.14
2050	0.28	0.95	0.37	0.12	0.34	1.21	0.49	0.13
2051	0.27	0.96	0.37	0.11	0.32	1.12	0.47	0.12
2052	0.25	0.82	0.36	0.11	***0.29***	0.98	0.44	0.12
2053	0.33	1.28	0.38	0.11	0.37	1.41	0.49	0.12
2054	0.30	1.10	0.38	0.11	0.32	1.18	0.46	0.12
2055	0.27	0.95	0.36	0.10	0.30	1.06	0.44	0.11
2056	0.29	1.04	0.41	0.10	0.32	1.16	0.45	0.11
2057	0.30	1.15	0.37	0.10	0.32	1.17	0.46	0.11
2058	0.25	0.87	0.38	0.10	0.27	0.91	0.43	0.11
2059	0.31	1.28	0.36	0.10	0.33	1.31	0.46	0.10
2060	0.25	0.89	0.35	0.09	0.26	0.93	0.40	0.10
2061	0.23	0.80	0.33	0.09	0.25	0.84	0.38	0.09
2062	0.25	0.90	0.34	0.09	0.26	0.91	0.38	0.10
2063	0.25	0.89	0.35	0.09	0.26	0.91	0.37	0.10
2064	0.25	0.92	0.36	0.09	0.27	0.97	0.38	0.10
2065	0.25	0.88	0.36	0.10	0.25	0.87	0.38	0.10
2066	0.30	1.25	0.34	0.09	0.31	1.26	0.40	0.09
2067	0.26	0.95	0.37	0.09	0.27	0.97	0.37	0.10

Notes:
1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-9
Modeled Year-of-Compliance for River Otter
Risk-Based Fish Concentrations
Upper Hudson River

River Otter - RI/FS TRVs (whole fish tissue)	**Modeled Year of Compliance**	
	LOAEL 0.3 PCBs mg/kg	**NOAEL 0.03 PCBs mg/kg**
Upper Hudson River Average		
No Resuspension (d004)	2035	> 2067
Total PCB 350 ng/L (sr04)	2035	> 2067
Total PCB 600 g/day (sr01)	2035	> 2067
Monitored Natural Attenuation	2052	> 2067
Upper Hudson River Section 1		
No Resuspension (d004)	> 2067	> 2067
Total PCB 350 ng/L (sr04)	> 2067	> 2067
Total PCB 600 g/day (sr01)	> 2067	> 2067
Monitored Natural Attenuation	> 2067	> 2067
Upper Hudson River Section 2		
No Resuspension (d004)	> 2067	> 2067
Total PCB 350 ng/L (sr04)	> 2067	> 2067
Total PCB 600 g/day (sr01)	> 2067	> 2067
Monitored Natural Attenuation	> 2067	> 2067
Upper Hudson River Section 3		
No Resuspension (d004)	2019	> 2067
Total PCB 350 ng/L (sr04)	2024	> 2067
Total PCB 600 g/day (sr01)	2020	> 2067
Monitored Natural Attenuation	2024	> 2067

Notes:
First year in which fish target concentrations are achieved are provided.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-10
Lower Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				Total PCB 350 ng/L (sr04)			
	River Mile 152	River Mile 113	River Mile 90	River Mile 50	River Mile 152	River Mile 113	River Mile 90	River Mile 50
1998	7.15	5.21	3.55	3.26	7.15	5.21	3.55	3.26
1999	4.53	4.12	3.30	3.01	4.53	4.12	3.30	3.01
2000	3.81	3.56	2.93	2.73	3.81	3.56	2.93	2.73
2001	4.50	3.54	2.66	2.49	4.50	3.54	2.66	2.49
2002	3.97	3.19	2.49	2.31	3.97	3.19	2.49	2.31
2003	3.42	2.82	2.26	2.10	3.42	2.82	2.26	2.10
2004	2.42	2.26	1.97	1.89	2.42	2.26	1.97	1.89
2005	2.27	1.95	1.69	1.67	2.27	1.95	1.69	1.67
2006	2.37	1.85	1.49	1.48	2.53	1.89	1.49	1.49
2007	1.93	1.71	1.35	1.34	2.37	1.86	1.40	1.36
2008	1.54	1.41	1.22	1.20	2.33	1.77	1.33	1.25
2009	1.21	1.15	1.06	1.05	2.03	1.53	1.18	1.12
2010	1.10	1.02	0.92	0.94	2.55	1.71	1.16	1.06
2011	1.25	1.01	0.84	0.86	5.16	2.57	1.35	1.10
2012	0.92	0.86	0.75	0.77	2.17	2.06	1.38	1.13
2013	1.02	0.82	0.68	0.71	1.78	1.63	1.28	1.11
2014	0.86	0.74	0.62	0.64	1.33	1.29	1.12	1.04
2015	0.72	0.65	0.56	0.59	1.04	1.04	0.96	0.94
2016	0.55	0.53	0.50	0.53	0.76	0.78	0.79	0.83
2017	0.46	0.45	0.44	0.48	0.54	0.60	0.65	0.73
2018	0.43	0.41	0.39	0.44	0.45	0.50	0.54	0.63
2019	0.34	0.35	0.35	0.40	0.35	0.39	0.44	0.54
2020	0.42	0.35	0.32	0.36	0.42	0.37	0.38	0.46
2021	0.41	0.34	***0.30***	0.34	0.41	0.36	0.34	0.41
2022	0.35	0.32	0.29	0.32	0.35	0.33	0.31	0.37
2023	0.30	***0.29***	0.27	***0.30***	0.30	***0.29***	***0.28***	0.33
2024	0.32	0.28	0.25	0.28	0.32	0.28	0.26	0.31
2025	0.35	0.30	0.25	0.27	0.35	0.30	0.26	***0.29***
2026	0.33	0.29	0.25	0.27	0.33	0.29	0.25	0.28
2027	***0.26***	0.26	0.24	0.26	***0.26***	0.26	0.24	0.27
2028	0.24	0.24	0.23	0.25	0.24	0.25	0.23	0.26
2029	0.29	0.25	0.22	0.24	0.29	0.25	0.22	0.25
2030	0.29	0.25	0.22	0.24	0.29	0.25	0.22	0.24
2031	0.25	0.24	0.21	0.23	0.25	0.24	0.21	0.23
2032	0.25	0.24	0.21	0.23	0.25	0.24	0.21	0.23
2033	0.23	0.23	0.21	0.23	0.23	0.23	0.21	0.23
2034	0.22	0.22	0.20	0.22	0.22	0.22	0.20	0.22
2035	0.35	0.25	0.21	0.22	0.35	0.25	0.21	0.22
2036	0.48	0.32	0.23	0.23	0.48	0.32	0.23	0.23
2037	0.57	0.39	0.26	0.24	0.57	0.39	0.26	0.24
2038	0.58	0.40	0.28	0.26	0.58	0.40	0.28	0.26
2039	0.48	0.39	0.29	0.27	0.48	0.39	0.29	0.27
2040	0.43	0.37	0.29	0.27	0.43	0.37	0.29	0.27
2041	0.30	0.32	0.28	0.27	0.30	0.32	0.28	0.27
2042	0.25	0.27	0.26	0.26	0.25	0.27	0.26	0.26
2043	0.29	0.26	0.24	0.25	0.29	0.26	0.24	0.25
2044	0.35	0.28	0.23	0.24	0.35	0.28	0.23	0.25
2045	0.33	0.28	0.23	0.24	0.33	0.28	0.23	0.24
2046	0.29	0.26	0.22	0.24	0.29	0.26	0.22	0.24

Notes:
Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Table 2-10
Lower Hudson River Average Largemouth Bass (Whole Fish)
PCB Concentration (in mg/kg)

	Total PCB 600 g/day (sr01)				**Monitored Natural Attenuation**			
Year	River Mile 152	River Mile 113	River Mile 90	River Mile 50	River Mile 152	River Mile 113	River Mile 90	River Mile 50
1998	7.15	5.21	3.55	3.26	7.54	5.30	3.55	3.24
1999	4.53	4.12	3.30	3.01	4.37	4.06	3.28	2.99
2000	3.81	3.56	2.93	2.73	4.01	3.56	2.91	2.71
2001	4.50	3.54	2.66	2.49	4.51	3.54	2.65	2.47
2002	3.97	3.19	2.49	2.31	3.91	3.17	2.47	2.28
2003	3.42	2.82	2.26	2.10	3.39	2.82	2.25	2.08
2004	2.42	2.26	1.97	1.89	2.39	2.23	1.96	1.88
2005	2.27	1.95	1.69	1.67	2.25	1.94	1.68	1.66
2006	2.49	1.86	1.49	1.49	2.34	1.86	1.49	1.47
2007	2.20	1.79	1.38	1.34	1.89	1.70	1.35	1.32
2008	1.97	1.60	1.27	1.23	1.57	1.42	1.21	1.20
2009	1.62	1.34	1.12	1.08	1.27	1.16	1.06	1.05
2010	1.73	1.30	1.02	1.00	1.36	1.13	0.94	0.95
2011	2.43	1.49	1.01	0.96	1.63	1.22	0.91	0.89
2012	1.32	1.20	0.96	0.90	1.30	1.11	0.86	0.83
2013	1.27	1.08	0.88	0.84	1.48	1.13	0.83	0.79
2014	1.01	0.92	0.78	0.77	1.27	1.03	0.79	0.74
2015	0.82	0.78	0.69	0.70	1.00	0.90	0.73	0.70
2016	0.61	0.61	0.60	0.63	0.76	0.72	0.65	0.64
2017	0.51	0.51	0.51	0.56	0.68	0.62	0.57	0.59
2018	0.47	0.45	0.45	0.50	0.65	0.58	0.51	0.53
2019	0.37	0.38	0.39	0.45	0.52	0.50	0.46	0.49
2020	0.45	0.37	0.35	0.40	0.68	0.51	0.42	0.44
2021	0.44	0.36	0.32	0.36	0.63	0.49	0.40	0.41
2022	0.37	0.34	0.30	0.34	0.51	0.45	0.38	0.39
2023	0.32	0.30	***0.28***	0.32	0.46	0.41	0.35	0.37
2024	0.33	***0.29***	0.26	***0.30***	0.48	0.40	0.34	0.35
2025	0.37	0.31	0.26	0.29	0.53	0.43	0.34	0.34
2026	0.34	0.29	0.25	0.28	0.48	0.40	0.33	0.33
2027	***0.26***	0.27	0.24	0.27	0.37	0.36	0.32	0.32
2028	0.25	0.25	0.23	0.26	0.35	0.34	***0.30***	0.31
2029	0.30	0.25	0.22	0.25	0.42	0.34	0.28	***0.30***
2030	0.30	0.25	0.22	0.24	0.40	0.34	0.28	0.29
2031	0.25	0.24	0.22	0.24	0.34	0.32	0.27	0.28
2032	0.26	0.24	0.22	0.24	0.35	0.32	0.27	0.28
2033	0.23	0.23	0.21	0.23	0.31	0.30	0.26	0.28
2034	0.22	0.22	0.20	0.23	***0.29***	***0.29***	0.25	0.27
2035	0.27	0.23	0.20	0.22	0.42	0.33	0.25	0.26
2036	0.23	0.22	0.20	0.22	0.54	0.38	0.27	0.26
2037	0.40	0.28	0.21	0.22	0.69	0.46	0.30	0.28
2038	0.65	0.38	0.24	0.23	0.65	0.47	0.32	0.29
2039	0.56	0.41	0.27	0.25	0.55	0.44	0.33	0.30
2040	0.51	0.40	0.29	0.26	0.48	0.42	0.33	0.31
2041	0.35	0.35	0.28	0.27	0.35	0.36	0.31	0.30
2042	0.29	0.30	0.27	0.27	0.28	0.30	0.28	0.29
2043	0.33	0.29	0.25	0.26	0.35	0.30	0.26	0.28
2044	0.38	0.31	0.25	0.25	0.42	0.32	0.26	0.27
2045	0.34	0.30	0.24	0.25	0.38	0.32	0.26	0.26
2046	0.30	0.27	0.23	0.24	0.33	0.30	0.25	0.26

Notes:
Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Table 2-11
Modeled Year-of-Compliance for River Otter
Risk-Based Fish Concentrations
Lower Hudson River

	River Otter - RI/FS TRVs (whole fish tissue)	
	LOAEL 0.3 PCBs mg/kg	**NOAEL 0.03 PCBs mg/kg**
Lower Hudson River RM 152		
No Resuspension (d004)	2027	> 2067
Total PCB 350 ng/L (sr04)	2027	> 2067
Total PCB 600 g/day (sr01)	2027	> 2067
Monitored Natural Attenuation	2034	> 2067
Lower Hudson River RM 113		
No Resuspension (d004)	2023	> 2067
Total PCB 350 ng/L (sr04)	2023	> 2067
Total PCB 600 g/day (sr01)	2024	> 2067
Monitored Natural Attenuation	2034	> 2067
Lower Hudson River RM 90		
No Resuspension (d004)	2021	> 2067
Total PCB 350 ng/L (sr04)	2023	> 2067
Total PCB 600 g/day (sr01)	2023	> 2067
Monitored Natural Attenuation	2028	> 2067
Lower Hudson River RM 50		
No Resuspension (d004)	2023	> 2067
Total PCB 350 ng/L (sr04)	2025	> 2067
Total PCB 600 g/day (sr01)	2024	> 2067
Monitored Natural Attenuation	2029	> 2067

Notes:
First year in which fish target concentrations are achieved are provided.

Table 2-12
Results for Average Dredging-Related Source Strength Estimated Fluxes

	INPUT				TSS-Chem RESULTS				PERCENT LOSS	
	PCB Production rate kg PCB/day	Sediment production rate kg solids/day	Silt Fraction unitless	TSS Silt Source Strength (1,2) (kg/s)	Net TSS Flux at 1 mile (2) (kg/day)	Net Total PCB Flux at 1 mile (2) (g/day)	Net Fraction Dissolved PCBs at 1 mile unitless	Concentration increase at 1 mile (ng/l)	TSS Loss at 1 mile %	PCB Loss at 1 mile %
River Section										
Section 1	57	2,099,921	0.37	0.077	2,303	78	0.35	14	0.11	0.14
Section 2	116	1,857,493	0.48	0.088	2,642	209	0.39	37	0.14	0.18
Section 3	45	1,563,927	0.48	0.074	2,225	81	0.40	14	0.14	0.18

Notes:
1. Source strengths apply to silt and finer particles only
2. Production rates are based on 7 days/week, 14 hours per day, 630 days in Section 1 and 210 days each in River Sections 2 & 3.
3. Values are based on river-wide volumetric flow of 4000 cfs.

Table 2-13
Resuspension Production, Release, and Export Rates from TSS-Chem and HUDTOX Models

Scenario	Sediment Removal Period	Dredging Location and Monitoring Station	Resuspension Production Rate of Sediment[1] (kg/s)	Resuspension Production Rate of Total PCB[2] (g/day)	Net TSS Flux at 1 mile from TSS-Chem (kg/s)	TPCB flux at 1 mile[3] (Resuspension Release Rate) (g/day)	TPCB Flux at Monitoring Stations from HUDTOX[4] (Resuspension Export Rate) (g/day)	TPCB Production Rate[6] (g/day)	Solids Production Rate[7] (kg/s)	Source Strength as Percentage of TPCB Removed[8] (%)	Resuspension Export Rate as Percentage of TPCB Removed[9] (%)
Evaluation Level - 300 g/day TPCB Flux at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	1.3	1,700	0.28	410	320	5.7.E+04	42	3%	0.56%
	May 1 - November 30, 2007	Section 1, TID	1.3	1,700	0.27	410	320	5.7.E+04	42	3%	0.56%
	May 1 - November 30, 2008	Section 1, TID	1.1	1,500	0.24	360	300	5.7.E+04	42	3%	0.53%
	May 1 - August 15, 2009	Section 1, TID	0.9	1,300	0.20	310	310	5.7.E+04	42	2%	0.54%
	August 16 - November 30, 2009	Section 2, Schuylerville	0.3	1,100	0.10	360	330	1.2.E+05	37	1%	0.29%
	May 1 - August 15, 2010	Section 2, Schuylerville	0.3	900	0.08	310	300	1.2.E+05	37	1%	0.26%
	August 16 - November 30, 2010	Section 3, Waterford	0.9	1,300	0.25	400	340	4.5.E+04	31	3%	0.75%
	May 1 - August 15, 2011	Section 3, Waterford	0.7	1,000	0.19	310	340	4.5.E+04	31	2%	0.75%
Control Level - 600 g/day TPCB Flux at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	2.6	3,600	0.57	820	620	5.7.E+04	42	6%	1.1%
	May 1 - November 30, 2007	Section 1, TID	2.6	3,600	0.57	820	630	5.7.E+04	42	6%	1.1%
	May 1 - November 30, 2008	Section 1, TID	2.3	3,100	0.50	720	620	5.7.E+04	42	6%	1.1%
	May 1 - August 15, 2009	Section 1, TID	2.0	2,700	0.43	620	590	5.7.E+04	42	5%	1.0%
	August 16 - November 30, 2009	Section 2, Schuylerville	0.7	2,300	0.21	730	620	1.2.E+05	37	2%	0.5%
	May 1 - August 15, 2010	Section 2, Schuylerville	0.6	1,900	0.17	630	590	1.2.E+05	37	2%	0.5%
	August 16 - November 30, 2010	Section 3, Waterford	1.9	2,700	0.52	810	660	4.5.E+04	31	6%	1.5%
	May 1 - August 15, 2011	Section 3, Waterford	1.4	2,100	0.40	630	650	4.5.E+04	31	5%	1.4%
Control Level - 350 ng/L TPCB Concentrations at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	5.6	7,600	1.2	1,700	1,200	5.7.E+04	42	13%	2.1%
	May 1 - November 30, 2007	Section 1, TID	5.6	7,600	1.2	1,700	1,200	5.7.E+04	42	13%	2.1%
	May 1 - November 30, 2008	Section 1, TID	4.9	6,700	1.1	1,500	1,300	5.7.E+04	42	12%	2.3%
	May 1 - August 15, 2009	Section 1, TID	4.2	5,700	0.91	1,300	1,200	5.7.E+04	42	10%	2.1%
	August 16 - November 30, 2009	Section 2, Schuylerville	2.7	8,300	0.75	2,500	2,000	1.2.E+05	37	7%	1.7%
	May 1 - August 15, 2010	Section 2, Schuylerville	2.3	7,100	0.64	2,100	2,000	1.2.E+05	37	6%	1.7%
	August 16 - November 30, 2010	Section 3, Waterford	7.5	10,900	2.1	3,100	2,200	4.5.E+04	31	24%	4.9%
	May 1 - August 15, 2011	Section 3, Waterford	5.8	8,400	1.6	2,400	2,300	4.5.E+04	31	19%	5.1%

Table 2-13
Resuspension Production, Release, and Export Rates from TSS-Chem and HUDTOX Models

Scenario	Sediment Removal Period	Dredging Location and Monitoring Station	Resuspension Production Rate of Sediment[1] (kg/s)	Resuspension Production Rate of Total PCB[2] (g/day)	Net TSS Flux at 1 mile from TSS-Chem (kg/s)	TPCB flux at 1 mile[3] (Resuspension Release Rate) (g/day)	TPCB Flux at Monitoring Stations[10] (Resuspension Export Rate) (g/day)	TPCB Production Rate[6] (g/day)	Solids Production Rate[7] (kg/s)	Source Strength as Percentage of TPCB Removed[8] (%)	Resuspension Export Rate as Percentage of TPCB Removed[9] (%)
Resuspension Standard - 500 ng/L TPCB Concentrations at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	9.4	12,800	2.0	2,800	2,100	5.7.E+04	42	23%	3.7%
	May 1 - November 30, 2007	Section 1, TID	9.3	12,700	2.0	2,800	2,100	5.7.E+04	42	22%	3.7%
	May 1 - November 30, 2008	Section 1, TID	8.2	11,200	1.8	2,500	2,100	5.7.E+04	42	20%	3.7%
	May 1 - August 15, 2009	Section 1, TID	7.1	9,600	1.53	2,100	2,100	5.7.E+04	42	17%	3.7%
	August 16 - November 30, 2009	Section 2, Schuylerville	3.5	10,900	0.99	3,200	2,700	1.2.E+05	37	9%	2.3%
	May 1 - August 15, 2010	Section 2, Schuylerville	3.0	9,300	0.84	2,800	2,700	1.2.E+05	37	8%	2.3%
	August 16 - November 30, 2010	Section 3, Waterford	11	16,600	3.2	4,800	3,500	4.5.E+04	31	37%	7.7%
	May 1 - August 15, 2011	Section 3, Waterford	8.8	12,800	2.5	3,700	3,500	4.5.E+04	31	28%	7.7%

Notes:
Numbers are rounded to 2 significant digits.
[1] Source strength represents the amount of solids being suspended to the water column at the dredge-head in kg/s. The value is obtained from the TSS-Chem model.
[2] TPCB flux for source strength is obtained by multiplying the solids source strength with the TPCB concentration in the sediment. The TPCB concentration for River Sections 1, 2, and 3 is 27, 62, and 29 mg/kg, respectively.
[3] Net TSS flux is the TSS-Chem model result at a distance 1 mile downstream of the dredge-head.This number is also the TSS flux input to the HUDTOX model.
[4] Values represent the amount of TPCB flux at the monitoring stations as predicted by HUDTOX.
[5] TPCB flux is obtained from TSS-Chem model. It is the TPCB flux at 1 mile downstream of the dredge-head. This is also the input TPCB flux to the HUDTOX model.
[6] TPCB production rate based on the total TPCB being removed in each river section (36,000 kg, 24,300 kg, and 9,500 kg of TPCB for River Sections 1, 2, and 3, respectively); assuming 7days/week, 14 hours/day, 630 days in River Section 1 and 210 days each in River Sections 2 and 3.
[7] Solids production rate based on the total sediment being removed including overcut (1.5x10^6 cy, 5.8x10^5 cy, and 5.1x10^5 cy of solids in River Sections 1, 2, and 3, respectively); assuming 7days/week and 14 hours/day, 630 days in River Section 1 and 210 days each in River Sections 2 and 3.
[8] Percentage is calculated as TPCB source strength divide by the TPCB production rate.
[9] Percentage is calculated as TPCB flux at the monitoring station divide by the TPCB production rate.
[10] TPCB flux is calculated based on the 500 ng/L at the far-field monitoring stations minus the mean baseline TPCB concentrations based on the GE water column samples data.

Table 2-14
Increase in PCB Mass from Settled Material 2-Acres Below the Target Area
Estimated Using the TSS-Chem Model Results

Management Level	Condition at Far Field Station	River Section	Total PCBs Length-Weighted Average Concentration (mg/kg) (0-6 inches)
Evaluation	300 g/day PCB Mass Loss	1	2.6
Control	600 g/day PCB Mass Loss	1	4.2
Control	350 ng/L	1	6.6
Evaluation	300 g/day PCB Mass Loss	2	2.0
Control	600 g/day PCB Mass Loss	2	3.3
Control	350 ng/L	2	9.1
Evaluation	300 g/day PCB Mass Loss	3	2.2
Control	600 g/day PCB Mass Loss	3	3.5
Control	350 ng/L	3	8.6

1. Mass/Area used to define the lateral extent of dredging in River Sections 1 and 2 is approximately 6.6 g/sq. m and 34 g/sq. m, respectively. In River Section 3, a mass/area was not used to select the areas in this way.

2. The length weighted average concentration was calculated assuming the concentration below the deposited PCBs is 1 mg/kg Total PCBs.

Table 3-1
Upper 95th Percentile Estimates of Total PCB Concentrations at TI Dam and Schuylerville Under Baseline Conditions

Units: ng/L

TID-West	May	June	July	August	Sept.	Oct. & Nov.
Prediction interval	368	368	212	149	119	297
TID-PRW2	May&June Low Flow (<5000 cfs)	May&June High Flow (>5000 cfs)	July and August	Sept.	Oct.	Nov.
Prediction interval	161	68	106	72	92	65
Schuylerville	May and June	July	August	Sept.	Oct.	Nov.
Prediction interval	195	99	107	85	118	107

Table 3-2
Summary of Sampling Frequency Requirements and Expected Error Rates

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples[1]	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV)									
Far Field									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 (1 sample/day for 1 week)	400 g/day	7.5	5	1
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 (1 sample/day for 1 week)	700 g/day	25	15	2
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 1 week	600 g/day	28 (7 samples routine + 21 samples control level)	700 g/day	5	4	3
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 (1 sample/day for 1 week)	400 ng/L	27.5	20	4
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 1 week	350 ng/L	28 (7 samples routine + 21 samples control level)	400 ng/L	10	5	5
	Evaluation to Control Level	300 g/day to > 600 g/day	1 week evaluation + 1 week	600 g/day	35 (14 samples evaluation level + 21 samples control level)	700 g/day	4	2	6
	Resuspension Standard Threshold	Confirmation of > 500 ng/L[2]	1 day routine + 1 day	500 ng/L	5 (1 sample routine + 4 samples confirmation)	400 ng/L	15	30	7
		Confirmation of > 500 ng/L (24 hours)[2]	1 day	500 ng/L	4 composites of 6 aliquots each	400 ng/L	5	7	8
	Routine to Control Level	Continuous Total PCB 1-week or 2-week deployment	1 week or 2 weeks	350 ng/L	2 composites of 56 aliquots each	400 ng/L	6.5	5	9
Suspended Solids Sampling Requirements (75% CV)									
Far Field									
	Routine to Evaluation Level	Far-field - Baseline to > 12 mg/L	1 day (3 hrs for 24 hrs)	14 mg/L	8 (discrete)	21 mg/L	27.5	12.5	10
			1 day (15 min for 24 hrs)	14 mg/L	96 (continuous)	21 mg/L	0.1	0.1	11
	Routine to Control Level	Far-field - Baseline to > 24 mg/L	1 day (3 hrs for 24 hrs)	26 mg/L	8 (discrete)	39 mg/L	27.5	12.5	12
			1 day (15 min for 24 hrs)	26 mg/L	96 (continuous)	39 mg/L	0.1	0.1	13
	Evaluation to Control Level	Far-field - 12 mg/L to > 24 mg/L	1 day evaluation + 1 day	26 mg/L	16 (discrete)	39 mg/L	15	5	14
			1 day evaluation + 1 day	26 mg/L	192 (continuous)	39 mg/L	0.5	< 0.5	15
Near Field									
	Routine to Control Level	Near Field - River Sections 1 and 3	6 hours (1 sample per 3 hours)	100 mg/L	3 (discrete)	150 mg/L	35	25	16
		Baseline to > 100 mg/L	6 hours (1 sample per 15 min)	100 mg/L	24 (continuous)	150 mg/L	6.6	5	17
	Routine to Control Level	Near Field - River Section 2	6 hours (1 sample per 3 hours)	60 mg/L	3 (discrete)	90 mg/L	35	25	18
		Baseline to > 60 mg/L	6 hours (1 sample per 15 min)	60 mg/L	24 (continuous)	90 mg/L	6.6	5	19
	Evaluation to Control Level	Near Field - River Sections 1 and 3	1 day (3 hrs for 15 hrs)	100 mg/L	5 (discrete)	150 mg/L	27.5	20	20
		Baseline to > 100 mg/L	1 day (15 min for 15 hrs)	100 mg/L	60 (continuous)	150 mg/L	0.7	0.5	21
	Evaluation to Control Level	Near Field - River Section 2	1 day (3 hrs for 15 hrs)	60 mg/L	5 (discrete)	90 mg/L	27.5	20	22
		Baseline to > 60 mg/L	1 day (15 min for 15 hrs)	60 mg/L	60 (continuous)	90 mg/L	0.7	0.5	23
	Routine to Evaluation Level	Near Field	3 hours (1 sample per 3 hours)	700 mg/L	2 (discrete)	1000 mg/L	40	30	24
		Baseline to > 700 mg/L	3 hours (1 sample per 5 min)	700 mg/L	36 (continuous)	1000 mg/L	16.5	5	25

Note

[1] Sampling frequency at the different action level can be found in Table 1-2 of Volume 1 of the document

[2] Null hypothesis for the 500 ng/L assumed that river conditions were not in compliance, for all other action levels, the null hypohesis assumed that river conditions were in compliance. See text for discussions.

Table 3-3
Summary of Sampling Frequency Requirements and Expected Error Rates for Automatic Sampler

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV)									
Far Field									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 g/day	0.1	<0.1	29
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	700 g/day	0.5	0.1	30
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 3 day	600 g/day	10 (7 samples routine + 3 samples control level)	700 g/day	0.5	<0.5	31
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 ng/L	1	1	32
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 3 day	350 ng/L	10 (7 samples routine + 3 samples control level)	400 ng/L	0.5	<0.5	33
	Evaluation to Control Level	300 g/day to > 600 g/day	2 day evaluation + 3 day	600 g/day	5 (composite sampling every 1 hour, 1 sample/day)	700 g/day	2	1	34

Table 4-1
Estimated 7-Day Total PCB Concentrations[1] Corresponding to the Evaluation Level (300 g/day) at the Schuylerville Monitoring Station

			Total PCB (ng/L)- Schuylerville Station[2]					
Flow (cfs)	Flow (m^3/s)	Total PCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
95% UCL Baseline Total PCB Concentration			**121**	**103**	**81**	**60**	**84**	**75**
2,000	57	105	226	208	186	165	189	180
2,500	71	84	205	187	165	144	168	159
3,000	85	70	191	173	151	130	154	145
3,500	99	60	181	163	141	120	144	135
4,000	113	53	174	155	133	113	136	128
4,500	127	47	168	149	127	107	131	122
5,000	142	42	163[3]	145	123	102	126	117
5,500	156	38	160	141	119	98	122	113
6,000	170	35	156	138	116	95	119	110
6,500	184	32	154	135	113	92	116	108
7,000	198	30	151	133	111	90	114	105
7,500	212	28	149	131	109	88	112	103
8,000	227	26	148	129	107	86	110	101
8,500	241	25	146	127	105	85	109	100
9,000	255	23	145[4]	126	104	83	107	99
9,500	269	22	143	125	103	82	106	97
10,000	283	21	142	124	102	81	105	96

Notes:

1. Total PCB concentrations are estimated based on the assumption of a 7-day per week operation, 14 hours per day for May to November (210 days). This is conservative since operating less than 7-days per week would increase the daily allowable Total PCB load. These values will be adjusted to reflect the planned period of operation once it is defined as part of the remedial design.
2. Shaded areas are the concentration at the mean flow for the month, based on flow estimates derived from the USGS flow data (1977-present).
3. Condition for June.
4. Condition for May.
5. The values provided in this table are based on historical data. These values will be revised prior to Phase 1 when baseline monitoring data are available and more is known about the operating schedule and production rate.

Table 4-2
Estimated 7-Day Total PCB Concentrations[1] Corresponding to the Control Level (600 g/day) at the Schuylerville Monitoring Station

			Total PCB (ng/L) - Schuylerville Station[2]					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
95% UCL Baseline Total PCB Concentration			**121**	**103**	**81**	**60**	**84**	**75**
2,000	57	210	331	313	291	270	294	285
2,500	71	168	289	271	249	228	252	243
3,000	85	140	261	243	221	200	224	215
3,500	99	120	241	223	201	180	204	195
4,000	113	105	226	208	186	165	189	180
4,500	127	93	215	196	174	154	177	169
5,000	142	84	205[3]	187	165	144	168	159
5,500	156	76	198	179	157	137	160	152
6,000	170	70	191	173	151	130	154	145
6,500	184	65	186	167	145	125	149	140
7,000	198	60	181	163	141	120	144	135
7,500	212	56	177	159	137	116	140	131
8,000	227	53	174	155	133	113	136	128
8,500	241	49	171	152	130	110	133	125
9,000	255	47	168[4]	149	127	107	131	122
9,500	269	44	166	147	125	104	128	119
10,000	283	42	163	145	123	102	126	117

Notes:

1. Total PCB concentrations are estimated based on the assumption of a 7-day per week operation, 14 hours per day for May to November (210 days). This is conservative since operating less than 7-days per week would increase the daily allowable PCB load. These values will be adjusted to reflect the planned period of operation once it is defined as part of the remedial design.
2. Shaded areas are the concentration at the mean flow for the month, based on flow estimates derived from the USGS flow data (1977-present).
3. Condition for June.
4. Condition for May.
5. The values provided in this table are based on historical data. These values will be revised prior to Phase 1 when baseline monitoring data are available and more is known about the operating schedule and production rate.

Table 4-3
Estimates of Baseline Concentrations at TI Dam, Schuylerville and Waterford[1]

Preliminary estimate of 95% UCL ($\overline{C_{bl}}$) for use in the equations presented in Section 4.1[1].

Station	Total PCB Concentrations (ng/L)						
	May	June	July	August	September	October	November
TID West[2]	181	205	151	106	83	241	241
TID PRW2[2]	111 [3] 47 [4]	111 [3] 47 [4]	71	71	50	64	45
Schuylerville	121	121	103	81	60	84	75
Waterford[5]	90	90	76	60	44	62	56

Notes:

[1] These values will be revised using the data collected during the baseline monitoring program. Similar values will be determined for Stillwater and Waterford from the baseline monitoring as well.
[2] The actual TID values are expected to fall between those obtain for TID West and TID PRW2.
[3] For flow < 5000 cfs.
[4] For flow > 5000 cfs.
[5] These values were estimated by multiplying the Schuylerville Total PCB concentrations by a dilution factor of 0.74 to account for additional tributary flow to Waterford.

Table 4-4

Far-Field Monitoring - Analytical Details

Parameter	Analytical Method / Instrument	Detection Limit Goal	Method Range	Accuracy	Precision	Sample Size	Holding Time	Sample Container	Preservation
Congener-specific PCBs (Total)	Green Bay or equivalent	0.05 ng/L/congener	Lab-specific and congener-specific	60-150%	40% RPD[1]	1 Liters	5/40[2] days	1 Liter amber glass	Maintain at 4^{o} C (± 2^{o} C)
Congener-specific PCBs (Water)	Green Bay or equivalent	0.05 ng/L/congener	Lab-specific and congener-specific	60-150%	40% RPD	20 Liters	5/40[2] days	4 Liter amber glass	Maintain at 4^{o} C (± 2^{o} C)
Congener-specific PCBs (Particle)	Green Bay or equivalent	1 µg/kg	Lab-specific and congener-specific	60-150%	40% RPD	200-800 mg	5/40[2] days	Amber glass	Maintain at 4^{o} C (± 2^{o} C)
DOC (TOC on filtered water)	Persulfate Digestion (415.2)	0.025 mg/L	50 µg/L to 10 mg/L	90-110%	20% RPD	2 x 40 mL (25 mL minimum)	28 days	VOA vial	Maintain at 4^{o}C H_2SO_4 pH =2
TSS	ASTM D 3977-97	0.5 mg/L (on 1 L sample)	0.5 to 2000 mg/L on 1 L sample	90 - 110%	20% RPD	1 Liter	7 days	4 Liter plastic	Maintain at 4^{o} C (± 2^{o} C)
TSS (using particle counter)	LISST Series	TBD	1.2 to 250 :m	TBD	TBD	25-50 mL	Field	Per instrument requirement	NA
TSS (fast turnaround)	Modified	1.0 mg/L (on 1 L sample)	0.5 to 2000 mg/L on 1 L sample	80 – 120 %	35% RPD	1 Liter	N/A	1 Liter plastic	None
Turbidity	YSI 6-Series	2 NTU	0 to 1000 NTU	± 5% or 3 NTU[3]	5%	25-50 mL	Field	Per instrument requirement	NA
Temperature	YSI 6-Series	0.15^{o} C	-5 to +45 ^{o}C	± 0.15^{o} C	± 0.15^{o} C	25-50 mL	Field	Per instrument requirement	NA
pH	YSI 6-Series	0.2 pH unit	0 to 14 pH units	± 0.2 pH unit	± 0.2 pH unit	25-50 mL	Field	Per instrument requirement	NA
Dissolved Oxygen	YSI 6-Series	0.2 mg/L	0 to 50 mg/L	0-20 mg/L: ± 2% or 0.2 mg/L[3]	15%	25-50 mL	Field	Per instrument requirement	NA
Conductivity	YSI 6-Series	0.001 mS/cm	0 to 100 mS/cm	± 0.5% or 0.001 mS/cm[3]	10%	25-50 mL	Field	Per instrument requirement	NA
TOC on SS – routine EPA 160.4	Volatile solids on SS as surrogate for TOC.	0.5% dry wt based on SS	± 0.3 mg assuming 0.1 mg sensitivity	± 10% or ± 0. 2 mg	± 0.4mg or 10%	100 mg solids based on 0.1 mg sensitivity	Lab	Glass only	NA
TOC for SS – periodic confirm	L Kahn – EPA Region II	0.5 % dry wt basis on SS	100 mg/kg	80 – 120%	RSD < 10 percent on quadruplicate	20 g filtered matter at 0.5%	Lab	Glass only	NA

Notes:

1 RPD = Relative Percent Difference; RPD criteria applicable only where sample concentrations = 5 x the sample reporting limit.

2 Holding times for extraction/analysis from time/date of sample collection.

3 Whichever is greater

NA Not applicable

TBD To Be determined

TOC Total Organic Carbon

ICP Inductively Coupled Plasma – atomic emission spectrometry

CV Cold Vapor atomic absorption

SS Suspended solids (i.e., particulate matter on filter)

mS milli-siemen

Table 4-5
Near-Field Monitoring - Analytical Details

Parameter		Method Analytical/Direct Reading	Detection Limit	Range	Accuracy	Precision	Sample Size	Holding Time	Sample Container	Preser-vative
Turbidity	Continuous	YSI 6-Series	2 NTU	0-1000 NTU	+/- 5% or 3 NTU	5%	NA	Field	NA	NA
TSS using particle counter	Discrete	LISST Series	TBD	1.2-250 um	TBD	TBD	25-50 mL	Field	NA	NA
TSS Laboratory	Discrete	ASTM D3977-97	0.01 mg/L	20%	LCS 90-110%	NA	TBD	7 days	plastic bottle	4 liter
TSS (fast turnaround)	Modified	1.0 mg/L (on 1 L sample)	0.5 to 2000 mg/L on 1 L sample	80 – 120 %	35% RPD	1 Liter	N/A	1 Liter plastic	None	1 liter
Dissolved Oxygen	Discrete	YSI 6-Series	TBD	0 to 500% air saturation	0-200 % : ±2% air sat. or ±2% of reading, whichever is greater; 200-500%	0.1% air saturation or 1% selectable	NA	Field	NA	NA
Conductivity	Discrete	YSI 6-Series	0.001 mS/cm	0 to 100 mS/cm	± 0.5% or 0.001 mS/cm3	0.1	25-50 mL	Field	NA	NA
Temperature	Discrete	YSI 6-Series	0.15o C	-5 to +45 oC	± 0.15o C	± 0.15o C	25-50 mL	Field	NA	NA

Notes:
1. Analytical Method ASTM D3977-97 Standard test method for determining sediment concentration in water samples.
2. TBD - to be determined

Table 4-6
Possible Study Areas for Nature of Release of PCB

Recommended Study Area	Sediment Type (Side Scan Sonar)	Sediment Type (ASTM Method D422 Classification)	Mean Tri+ PCB Concentrations[1] (mg/kg)
1	IV	CL, SI, FS, MS	10
2	IV	FS, MS	30
3	II	MS	11
4	IV	FS	15
5	IV	CL, SI, FS, MS	39
6	I	SI, FS	15
7	II	FS, MS	14
8	I	SI, FS, MS	8
9	II	FS	13
10	I	CL, SI, FS	14
11	I	FS	12
12	I	CL, SI, FS	15
13	I	CL, SI, FS	28

Note:

[1] Mean Tri+ concentrations are based on the length weighted averages of the entire core at location. Concentration represents the mean of draft dredge areas. Note that the draft dredge area boundaries have not yet been approved by the USEPA.

Table 4-7
Recommended Study Areas for Nature of Release of PCB

Recommended Study Area	Sediment Type (Side Scan Sonar)	Sediment Type (ASTM Method D422 Classification)	Tri+ PCB Entire Core LWA Concentrations (mg/kg)
1	IV	CL, SI, FS, MS	10
2	IV	FS, MS	30
3	II	MS	11
6	I	SI, FS	15
10	I	CL, SI, FS	14

Note:

[1] Mean Tri+ concentrations are based on the length weighted averages of the entire core at location. Concentration represents the mean of draft dredge areas. Note that the draft dredge area boundaries have not yet been approved by the USEPA.

Table 4-8
Resuspension Criteria (alternate)[1]

Parameter		Resuspension Standard Threshold		Control Level		Evaluation Level	
		Limit	Duration	Limit	Duration	Limit	Duration
Far-Field PCB Concentration	Total PCBs	500 ng/L	Confirmed Occurrence	350 ng/L	4-day running average (composite sampling every 1 hour, 1 sample/day)		
Far-Field Net PCB Load[3]	Total PCBs			65 kg/year[4]	Dredging Season		
	Total PCBs			600 g/day	3-day running average (composite sampling every 1 hour, 1 sample/day)	300 g/day	2-day running average (composite sampling every 1 hour, 1 sample/day)
	Tri+ PCBs			200 g/day		100 g/day	
Far-Field Net Suspended Solids Concentration[5,6]	All Sections			24 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	12 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
Near-Field (300 m) Net Suspended Solids Concentration[7]	Sections 1 & 3			100 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	100 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
	Sections 2			60 mg/L		60 mg/L	
Near-Field (100 m and Channel-Side) Net Suspended Solids Concentration[7]	All Sections					700 mg/L	3 continuous hrs. running average.

Notes:
1. Implemention of the criteria is described in Section 3.
2. Engineering contingencies for the Control Level will include temporary cessation of the operation.
3. Net increases in PCB load or suspended solids concentration refers to dredging related releases over baseline as defined in the text.
4. During Phase 1, half of the anticipated average production rate will be achieved. As a result, the total allowable export for Phase 1 is half of the fullscale value of 130 kg/year for a total of 650 kg for the entire program. This is equivalent to the 600 g/day Total PCB release at the target productivity schedule, during the dredging season from
5. The increased far-field monitoring required for exceedance of suspended solids criteria must include a sample timed so as to capture the suspended solids plume's arrival at the far-field station.
6. The monitoring requirements for exceedance of the suspended solids action levels are increased frequency sampling at the nearest far field station. The increased frequency at this station will be the same as the frequency required for the PCB action levels.
7. All remedial operations will be monitored in the near-field during Phase 1, including backfilling.